Board

Date: **30 January 2018**

Item: **Tram Overturning at Sandilands, Croydon on 9 November 2016 – RAIB and TfL Investigations and Non-Operational Incident Responses Update**

This paper will be considered in public

1 Summary

1.1 On Wednesday 9 November 2016, London Trams tram number 2551 travelling from New Addington towards East Croydon overturned on the approach to Sandilands tram stop on a curved track which has a permanent speed restriction of 20km/h. The tram was travelling at approximately 73km/h. Of the 70 people on board, seven lost their lives and 62 people were injured, 19 seriously.

1.2 Our thoughts remain with all those affected and we will continue to do all we can to offer our support.

1.3 The purpose of this paper is to:

(a) summarise the Rail Accident Investigation Branch's (RAIB's) investigation into the Tram overturning and derailment at Sandilands on 9 November 2016;

(b) update the Board on the findings of TfL's independent investigation;

(c) show the progress to date against the recommendations arising from each investigation and measures introduced; and

(d) update the Board on the non-operational activities underway and planned to assist all those affected by the tragedy.

Investigation Reports and Safety Measures Introduced

1.4 The Office of Rail and Road (ORR) and British Transport Police (BTP) are also conducting investigations. We continue to provide support to these agencies during their investigations.

1.5 Since the incident, we have introduced a number of safety measures to the tram network whilst awaiting the outcome of our own and RAIB's investigations. We have installed chevrons and speed-activated warning signs at significant bends, lowered the maximum speed limit across the network, and improved the protection that tram windows and doors provide

passengers. We have also rolled out a Driver Protection Device that detects the attention state of our drivers and intervenes should this fail.

1.6 We also continue to work with the wider tram industry on these improvements and will continue to work with them to implement the recommendations from the RAIB's report which apply across the industry.

1.7 Four separate investigations were undertaken into the tragic incident.

(a) RAIB as the UK's independent railway accident investigation organisation undertook the investigation to understand the causes of the accident and provide recommendations for industry learning;

(b) TfL commissioned an independent investigation seeking to identify root causes and produce recommendations specifically related to the operation of the Croydon Tram system;

(c) The ORR is seeking to identify if there were any breaches of health and safety legislation; and

(d) The BTP is undertaking an investigation which is focussed on whether there was any criminal action.

1.8 The RAIB published its report on 7 December 2017, this paper contains the TfL commissioned report, and the ORR and BTP investigations are ongoing.

Non-operational Incident Responses

1.9 We have worked hard to ensure that those affected by the overturning are being provided quickly with all appropriate support and assistance. This has been provided through interim payments, counselling and therapeutic support as necessary. The TfL Sarah Hope Line, run by specially trained staff, remains available to all those affected and continues to provide help with counselling, rehabilitation, compensation and other activities to support those affected. We have also provided support and counselling to staff as required.

1.10 We are working with the BTP, London Borough of Croydon, claimants' solicitors and a survivors' group to remain in contact with and offer continuing communications with those affected about the overturning and derailment, the investigations into the causes, the infrastructure and other improvements which have been made, the Coroner's Inquest and the criminal and regulatory steps which have yet to commence.

Safety, Sustainability and Human Resources Panel

1.11 Since the tragedy at Sandilands, the Panel has been kept fully informed of TfL's operational and non-operational response and the progress of the investigations.

1.12 On 22 January 2018, the Safety, Sustainability and Human Resources Panel considered papers on the RAIB and TfL investigations and on the Non-Operational Incident Responses.

1.13 The key issues raised by the Panel were:

(a) it welcomed the report from the RAIB and the SNC-Lavalin report undertaken for TfL, endorsed the recommendations in both reports and supported the action taken to date against the SNC-Lavalin recommendations and RAIB recommendations placed on TfL:

(b) it recommended that TfL ensure it had oversight of the implementation of the recommendations of the RAIB report that were directed at Tram Operations Limited and other parties;

(c) it supported TfL's proposal to consider how the lessons learned could be applied across the tram industry and other transport operators;

(d) TfL would consider how the lessons learned would be applied across all of TfL's operations, including how safety was reflected in its contracts and how the public was encouraged and enabled to raise safety concerns;

(e) TfL should review its evacuation procedures to ensure that they recognised the different needs or requirements of passengers including a broad range of disabilities;

(f) the Panel welcomed the support provided by TfL to those affected by the tragedy.

1.14 The Panel will continue to be kept informed of progress on the outstanding investigations. The quarterly Health, Safety and Environment performance report will include regular updates on progress against the recommendations of all of the investigations.

2 Recommendation

2.1 **The Board is asked to note the paper.**

3 The Rail Accident Investigation Branch (RAIB) Investigation

3.1 The RAIB published its report into the tram overturning incident at Sandilands on 7 December 2017. The report can be found here

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/665906/R182017_171207_Sandilands.pdf

3.2 The RAIB identified that the immediate cause of the tram overturning was that it was travelling too fast to negotiate the curve and the causal factors for which were that the tram did not slow down to a safe speed before entering Sandilands south curve because the driver did not apply sufficient braking. The report states that although some doubt remains as to the reasons for the driver not applying sufficient braking, the RAIB has concluded that the most likely cause was a temporary loss of awareness of the driving task due to a period of low workload, which possibly caused him to microsleep. It is also

possible that, when regaining awareness, the driver became confused about his location and direction of travel.

3.3 The RAIB found no evidence that the driver's health or medical fitness contributed to what happened but state that although highly unlikely an undetected medical reason cannot be discounted.

3.4 The investigation also considered whether the driver may have been fatigued. It concluded that the driver's rostered hours should not have caused an increased risk of fatigue on the morning of the accident over and above his typical shift pattern, but that there is some evidence that the driver's reported sleep pattern may have incurred a sleep debt. When people have a sleep debt they can experience deteriorations in performance and alertness. One manifestation of this is a propensity to fall asleep briefly during waking hours, even when driving. These are known as microsleeps. Low workload and a lack of associated stimulation can increase the likelihood of a person microsleeping. It is therefore possible that a microsleep was a factor in the driver's loss of awareness on the morning of the accident.

3.5 The RAIB found that the risk of trams overturning on curves was not properly understood by the tramway and so there were insufficient safety measures. It also found that those that died and many of the serious injuries were as a result of falling through the windows or doors as the tram tipped over.

Recommendations

3.6 The RAIB has made 15 recommendations to improve safety on UK trams. These relate to action in five main areas:

(a) The use of modern technology to intervene when trams approach hazardous features too fast, or when drivers lose awareness of the driving task;

(b) Tramways need to promote better awareness and management of the risk associated with tramway operations;

(c) Work needs to be done to reduce the extent of injuries caused to passengers in serious tram accidents, and to make it easier for them to escape;

(d) There needs to be improvements to safety management systems, particularly encouraging a culture in which everyone feels able to report their own mistakes; and

(e) Greater collaboration is needed across the tramway industry on matters relating to safety

3.7 Two of the recommendations are addressed directly to us (London Trams); two to Tram Operations Limited (TOL) who operate the trams on our behalf; two jointly between us and TOL; two to our regulator, the Office of Rail and Road (ORR); three jointly on UK Tram operators and owners and four to UK

tram operators, owners and infrastructure managers. (These latter two categories involve us).

3.8 As some of these recommendations need to be implemented by co-operation between the individual operators, the RAIB has recommended the establishment of a permanent body to facilitate a long term cooperative approach to UK tramway safety, which will require both suitable funding and access to data from all UK tramways.

3.9 To support cross industry learning, the RAIB report also includes safety advice to the Department for Transport and the bus industry, in relation to the strength and containment capability of windows and doors on buses and coaches.

3.10 A summary of the recommendations and progress against those RAIB recommendations placed on us or including us and those from our own investigation is shown in Appendix 2.

3.11 TfL, via London Trams, is represented on the UK Trams Sandilands Sub-Committee, established to specifically consider RAIB's findings and coordinate a response, and take action, on behalf of the UK Tram Industry. Where we have developed our own solutions to the recommendations, we have shared these with the wider industry and will continue to do so. We will also continue to engage with the UK Tram Industry to input to and adopt the outcomes of the wider recommendations/actions.

3.12 Future progress updates against these actions will be included in the quarterly Health, Safety Environment performance report to the Safety Sustainability and Human Resources Panel.

4 TfL Investigation

4.1 SNC-Lavalin, the company undertaking our independent investigation has concluded its report. The British Transport Police family liaison officers shared the findings of the report with the bereaved families on our behalf prior to its issue.

4.2 The report is included as Appendix 1. Its findings support those in the RAIB's report, with its recommendations focussed on London Trams. The immediate cause of the tragic incident was the tram speed not being reduced to below its overturning speed as it entered the curve at Sandilands Junction. The report discounts a number of possible theories namely:

(a) obstruction(s) on the infrastructure;

(b) failure of the infrastructure, control systems or tram; and

(c) malicious or deliberate act of the driver; distraction of the driver from a mobile phone or radio.

4.3 The report concludes that there are two possible contributory chains of events:

(a) the driver of the tram did not identify the need to brake the tram in the approach to the Sandilands curve due to a temporary loss of situational awareness; and

(b) the driver of the tram did not identify and act on braking cues in the approach to the Sandilands curve due to incapacitation.

4.4 The report also concludes that in both cases the system design does not provide adequate engineering controls for foreseeable human failures that could have resulted from temporary loss of or lack of situational awareness or from incapacitation.

4.5 The report states that completion of investigations by others (e.g. RAIB, ORR) may enable one chain of events to be eliminated and to confirm the other as the most likely causal chain.

Recommendations

4.6 The report makes eight recommendations under the following categorisations:

(a) primary recommendations which arise directly from the events leading to the incident; these relate to a review of:

i. the available cues to the driver of the braking points and the approaching curve;

ii. the traction brake controller driver's safety device design; and

iii. the arrangements for the monitoring and management of fatigue and fitness to work;

(b) secondary recommendations, which arise from topics either relating indirectly to the incident or that would have affected the incident and resulting events; these relate to a review of:

i. the arrangements for the monitoring and management of speeding; and

ii. route risk assessments and network risk model to reflect new understanding of risk arising from the Sandilands investigation; and

(c) observations that are recommendations based on other areas that can be improved; they relate to:

i. review of mechanisms used to promote organisational learning;

ii. review of near miss reporting mechanisms; and

iii. consider the feasibility of increasing containment of tram vehicles.

4.7 A summary of progress against these recommendations and those made by RAIB which are addressed to or involve us is shown in Appendix 2.

5 Safety Measures introduced since the incident

5.1 Since the incident we have introduced a number of additional safety measures to our tram network, including:

(a) we have implemented a permanent speed reduction across the London tram network meaning the maximum speed trams can travel will be 70kpm (previously 80kph). Step down speed signage (to 20kph) has also been installed at four locations, providing a graduated reduction in allowable line speed on approach to sharp curves (RAIB recommendation 5; TfL recommendation 1);

(b) Chevron signs have been installed at Sandilands and at the three other significant bends to provide an additional visual cue for drivers. The number of speed signs has been increased and additional lineside digital signage provides added speed warnings to drivers (RAIB recommendation 5; TfL recommendation 1);

(c) an in-cab driver protection device has been fitted to all trams which is now in service. Any sign of driver distraction or fatigue will result in the driver being alerted immediately (RAIB recommendation 4);

(d) we are continuing to work with safety experts to test various options to strengthen the glass fitted to trams (RAIB recommendation 6; TfL recommendation 8);

(e) work on developing an in-cab driver alert system for monitoring and managing tram speed, including the automatic application of emergency brakes is continuing (RAIB recommendation 2; TfL recommendation 2);

(f) the adoption of iBus technology on the tram network as a package of safety improvements – this is refereed to as iTram;

(g) potential track modifications are under consideration. We are currently tendering for a concept design in order to assess potential benefits;

(h) we are working to improve locally powered emergency lighting and are developing a specification for the tram fleet which will prevent unintentional interruption during an emergency (RAIB recommendation 7); and

(i) the CCTV recording system has been replaced and upgraded. (RAIB recommendation 14).

5.2 We are continuing to work with the wider tram industry on these improvements and have arranged a second trams summit to take place at the beginning of February 2018, where we can consider progress to date and possible further improvements. At this summit we will also share the lessons

learnt from our investigation, in addition to considering the recommendations arising from RAIB's investigation.

5.3 Within TfL, we are reviewing all the recommendations from both RAIB's and our own investigation reports to identify and implement any wider learning across our organisation and via our contractors and partners. Specifically we have identified the following actions to take forward, as a priority, within our main operational business areas (TfL Bus Operators, London Underground, Commercial Development, Major Projects, and London Rail) and any other of our transport undertakings we consider relevant.

- Strengthen the arrangements for monitoring and managing fatigue risk
- Review our risk assessment processes and the effectiveness of controls to reflect the understanding of risk from the Sandilands incident and that they are capable of identifying and correctly assessing all significant risks
- Review whether the preferred glazing solution for trams is appropriate for our other transport types to improve passenger containment
- Review our mechanisms for promoting and embedding organisational learning

5.4 The Trams Governance, Safety and Risk meeting has been established which comprises senior representatives from FirstGroup and TfL to provide assurance of the infrastructure and operator mitigations. (FirstGroup operate the trams on our behalf through Tram Operations Limited). It also provides a Forum for us to review FirstGroups safety performance and management arrangements. For example, we continue to monitor the enhanced driver management arrangements FirstGroup has put in place, which includes the more frequent programme of speed checks, fatigue management and counselling.

5.5 As part of our assurance process, and as reported to the November 2017 Safety, Sustainability and Human Resources Panel meeting, TfL's Internal Audit team undertook an audit of FirstGroup's fatigue management process. A number of recommendations were made where FirstGroup's arrangements differed from the guidance issued by the ORR. FirstGroup has engaged a fatigue specialist, approved by us, who is reviewing their fatigue management process to address the recommendations made in the audit.

6 Investigation Reports Next Steps

6.1 Following the issue of the RAIB report, and formal notification of its recommendations, we will formally respond to these describing what actions we are taking to address the recommendations.

6.2 We will continue to report progress against the RAIB's and our own recommendations to the Safety, Sustainability and Human Resources Panel via the quarterly Health Safety and Environment report. This update will also

continue to note the progress of implementation of the additional safety measures described in Section 5 of this report.

6.3 We will implement the relevant lessons learnt from both investigations more widely across our operational businesses.

6.4 We will continue to provide support to the ORR and BTP, as required, until their investigations are complete.

6.5 We will continue to work with the wider Tram industry to ensure all the RAIB's recommendations are actioned and tramway safety continues to improve.

7 Non-Operational Incident Responses

Support

7.1 Our thoughts remain with those affected by the tragic event. We remain focused on doing everything we can to offer support to all those affected and are dealing with requests for support quickly.

7.2 TfL's Sarah Hope Line, run by specially trained and dedicated TfL staff, remains available to all those affected to provide practical, financial and emotional help and also to make referrals for counselling and specialised support. The volume of calls and contacts related to the overturning which are being dealt with by the Sarah Hope line has now reduced. Since the overturning, we have taken more than 450 calls from bereaved families and passengers, and continue to make contact with people periodically to ensure they are continuing to receive the support they need.

7.3 In addition to direct contact with those affected, a page was created on the TfL website shortly after the overturning for the purpose of providing access to information and documents and providing up to date information relevant to the incident and the various investigations into the causes of the overturning and derailment: tfl.gov.uk/modes/trams/croydon-tram-derailment. The page will continue to be displayed and updated for the foreseeable future.

7.4 Working closely with TfL's insurers and claims handlers and the tram operator, we have been in touch with everyone injured who has notified us of a claim and also with the dependents of the people who lost their lives to confirm that liability is admitted in respect of their civil claims, to offer interim payments and other support with travel and logistical arrangements as needed, such as offers of assisted and subsidised travel for those injured or otherwise affected, to help regain confidence in the system. We are proactively staying in contact with all those affected to be available to provide continued support as and when needed.

7.5 To date more than £2.2m has been paid for compensation, counselling, rehabilitation and other activities to support those affected.

Lessons Learned – non-operational

7.6 We have reviewed our response to the overturning and derailment from an administrative handling perspective, (as opposed to an incident management or operational perspective).

7.7 The review concluded that the Sarah Hope Line operated effectively to co-ordinate contact with those affected and was a visible, identifiable point of contact for relatives of those affected, co-ordinating with other agencies to provide a clear conduit to ongoing support and claims handling. We are now considering what training can be provided to staff within the wider customer contact operation, as well as appointing a standby incident management resource, in order to provide additional support for such incidents in future.

7.8 The Gold/Silver/Bronze command structure used in major incidents was implemented effectively. We are now considering enhancing procedures to provide for circumstances where the incident site is not close to the operations centre to strengthen lines of communication and administrative support arrangements.

7.9 There have generally been good levels of engagement between all agencies involved and protocols were quickly put in place so that information could be shared appropriately, for example to enable counsellors to be given details of the people they needed to be supporting. We are extending existing standing arrangements for information sharing with agencies to facilitate the handling of major incidents.

7.10 We have updated our processes for identifying any customer contact, whether made directly to TfL or to another operator of TfL services, which raises concerns about safety-related issues. This updated process will enable us to undertake more detailed trend analysis and identify circumstances where preventative action might be needed, as well as ensuring we can fully track all responses to such contact from customers;

7.11 Our usual processes for handling press matters, including interaction with the press offices of other agencies, have worked well

7.12 Some of the initial direct communication with those affected was perceived as impersonal. We are reviewing processes to ensure that communication with those affected is appropriately personal and handled sensitively, particularly where we are unable to make contact directly and instead rely on another agency to make contact.

Personal Injury and Fatal Accident claims

7.13 TfL and the tram operator, Tram Operations Limited (a subsidiary of FirstGroup), are jointly insured in relation to the overturning and derailment and have worked together to support the insurers and claims handlers to respond to claims. We have agreed to share equally any costs arising which may not be covered by the insurance.

7.14 To date we have received 87 separate claims. Eighteen of those have now been resolved, including two of the claims related to the seven fatalities. Our approach has been to be open to settlement proposals and to ensure that fair settlements are reached.

7.15 In total to date, the Sarah Hope Line and insurers have paid over £2.2m in settlements, interim payments, funeral expenses, medical, counselling and therapeutic treatments and legal costs have been paid. We have proactively maintained contact with claimants and their solicitors to keep in touch over their progress with the preparation of their claims, to repeat our offers of interim payments to limit or alleviate financial hardship as far as we can and to look for ways in which we can assist those who have been affected.

7.16 We anticipate that the majority of the claims will be settled by the end of 2018.

Continuing contact and longer term relationships

7.17 At the request of the partner of one of the seriously injured passengers, the BTP coordinated arrangements for a discussion group for approximately 20 people and their partners to discuss how they can support each other. The organiser reported that the event went well. We proposed a special tram journey for this group which was run and a visit to the accident site arranged in May 2017 for those affected by the incident.

7.18 A number of people from that group generously gave their time to participate in interviews about their experience of the incident and the effect which it has had on them and their families. Recordings of these interviews have been used as part of safety training for senior TfL staff

7.19 Plans are also being made following the release of the RAIB report for further meetings with others who have been affected.

7.20 We are working with the representatives of the families of those who lost their lives in the incident to agree costs for them to be represented at the Coroner's Inquest which will be held at a date yet to be fixed. We will continue to support and assist them as necessary in relation to the Inquest.

7.21 Memorials remembering those who lost their lives were unveiled on the first anniversary of the overturning at Sandilands Junction and in New Addington. TfL offered to cover the costs associated with the memorials, but the London Borough of Croydon chose to fund this cost itself.

7.22 We recognise that reports associated with the various investigations into the causes of the overturning are distressing to bereaved families and passengers. We continue to work with the BTP, in particular their family liaison officers, to ensure that families and passengers are notified of developments, such as the publication of TfL's independent investigation report undertaken by SNC-Lavalin, in advance.

7.23 Where appropriate, we continue to take advice from Kenyon International, a disaster management specialist, to ensure that we manage our response to the tragedy in accordance with best practice. Steps have begun to put in place stand by arrangements with a disaster management specialist on an ongoing basis.

7.24 TfL has met with representatives of the London Borough of Croydon several times in the past year to discuss the impact of the overturning on the broader New Addington community and the support that may be required over coming years. A support package is in development with the council.

7.25 The use of the Sarah Hope Line and the other non-operational activities which have been undertaken in relation to Sandilands have given rise to a number of lessons learned for TfL but could also provide useful learning which could be shared with other organisations and sectors with responsibilities for major incident response. We will identify appropriate mechanisms to allow that learning to be shared and utilised as far as possible.

List of appendices to this report:

Appendix 1 – SCN Lavalin independent investigation into the tram derailment at Sandilands junction 9 November 2016.

Appendix 2 – A summary of and progress against the SNC Lavalin recommendations and RAIBs recommendation placed on TfL

List of Background Papers:

None

Contact Officer: Gareth Powell, Managing Director, Surface Transport
Number: 020 3054 0180
Email: GarethPowell@.tfl.gov.uk

Appendix 1

SNC·LAVALIN

Independent investigation into the tram derailment at Sandilands Junction, 9 November 2016

Report No: RTUKR-T39073-001

snclavalin.com

10 January 2018

NOTICE

This document contains the expression of the professional opinion of SNC-Lavalin Rail & Transit Limited (SNC-Lavalin) as to the matters set out herein, using its professional judgment and reasonable care. It is to be read in the context of the Terms of Reference dated 24 November 2016 between SNC-Lavalin and Transport for London, and the methodology, procedures and techniques used, SNC-Lavalin's assumptions, and the circumstances and constraints under which its mandate was performed. This document is written solely for the purpose stated in the Agreement and for the sole and exclusive benefit of the Client, whose remedies are limited to those set out in the Agreement. This document is meant to be read as a whole, and sections or parts thereof should thus not be read or relied upon out of context.

SNC-Lavalin has, in preparing any cost estimates, followed methodology and procedures, and exercised due care consistent with the intended level of accuracy, using its professional judgement and reasonable care, and is thus of the opinion that there is a high probability that actual costs will fall within the specified error margin. However, no warranty should be implied as to the accuracy of estimates. Unless expressly stated otherwise, assumptions, data and information supplied by, or gathered from other sources (including the Client, other consultants, testing laboratories and equipment suppliers etc.) upon which SNC-Lavalin's opinion as set out herein is based has not been verified by SNC-Lavalin; SNC-Lavalin makes no representation as to its accuracy and disclaims all liability with respect thereto.

SNC-Lavalin disclaims any liability to the Client and to third parties in respect of the publication, reference, quoting, or distribution of this report or any of its contents to and reliance thereon by any third party.

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1 Executive Summary

The incident and consequences

At about 06:07 hrs on Wednesday 9 November 2016, London Trams (LT) tram No 2551, travelling from New Addington towards East Croydon, overturned on a 30m radius curved track with a Permanent Speed Restriction (PSR) of 20km/h, on the approach to Sandilands tramstop.

Of the 70 people on board, seven lost their lives and 62 people were injured (including the driver), 19 seriously. Tram No 2551 is a Bombardier CR4000 unit operated by Tram Operations Limited (TOL) on behalf of LT.

The overturned tram impacted an overhead electricity stanchion, lineside equipment cabinets as well as rails being stored nearby. Significant damage was sustained to both the tram and the adjacent infrastructure.

TOL, LT and Transport for London (TfL) implemented their respective emergency plans and responded to the incident. Tram services were resumed east of Croydon at 12:30 on Friday 18 November.

This independent investigation was commissioned in order to:

- Record the events and state of the related systems before and after the incident
- Identify the causal chain including the initiating event, immediate causes, contributory and root causes.
- Formulate recommendations to address the findings.

Operating agreement

Under the current Operating Agreement, TOL (the current Transport Undertaking (TU), as defined by The Railways and Other Guided Transport Systems (Safety) Regulations (2006) (ROGS) [R-6]) is responsible for the safe operation of the trams.

LT (a subsidiary of TfL) has current responsibility for the provision of the infrastructure maintenance (since 2011) and for the tram maintenance (since 2014) and have therefore assumed responsibility as the Infrastructure Manager (IM) (as defined by ROGS).

Under ROGS, neither the IMs nor the TUs of a tramway system require Safety Certification or Safety Authorisation, but are required to operate their own Safety Management System (SMS).

The system was originally given approval, as a private consortium (Tramlink), to operate services by Her Majesty's Railway Inspectorate (HMRI) in 2000. TfL took over Tramlink in 2008.

Methodology

The findings of several workstreams are presented together in a causal chain diagram. This identifies the initiating event that led to the incident along with immediate and other contributory factors that contributed to the incident. The investigation is partially complete, pending review of further information from TOL and information retained by Rail Accident Investigation Branch (RAIB) and British Transport Police (BTP). This investigation has not had access to the tram driver, or his records, and has had no opportunity to interview him.

Findings

The causal chain is described as two possible contributory chains, either one of which is credible. Completion of investigations may enable one to be eliminated to confirm one as the most likely causal chain. The order in which they are presented gives no indication as to which is considered most likely. This report describes the initiating event and immediate

cause as shared conclusions, and then discusses both the probable contributory and associated root causes in turn.

Initiating event

- The initiating event of the incident is that tram 2551 entered the Sandilands curve at approximately 73km/h, significantly above the 20km/h PSR in place. This resulted in the tram losing contact with the rails, overturning, striking several items of infrastructure and coming to rest on its right hand side (relative to the direction of travel).

Immediate cause

- The immediate cause was the tram speed not being reduced to below its overturning speed as it entered a curve of approximately 30m radius at Sandilands Junction.

Contributory Causes (1) – Loss of situational awareness

- The system does not provide conspicuous warning/cues to the driver on where to operate the brakes of the tram on the approach to the hazard of the 30m radius curve and junction. The braking is required to ensure that the tram speed is below the tram overturn speed, is able to stop as required for the signal, and is controlled through a 20 km/h PSR on the curve.
- Under this theory, the driver became disorientated as to the location and/or direction of travel between Lloyd Park and approach to Sandlilands curve and did not initiate braking at the expected/required point on the approach to the curve.
- Visibility of the Sandilands curve, speed restriction signage and signal SNJ07S is achievable after the required point of first braking. Later sighting of the curve and signage offers little opportunity for the driver to recover from earlier failure to reduce the speed of the tram.
- The system did not detect or control excessive speed of trams.

Root Cause (1) – Loss of situational awareness

- The driver of the tram did not identify the need to brake the tram in the approach to the Sandilands curve due to a temporary loss of situational awareness.
- The system design does not provide adequate engineering controls for all foreseeable human failures that could result in a temporary loss of or lack of situational awareness.

Contributory Causes (2) – Incapacitation of driver

- The Driver Management systems may not have prevented the driver booking onto his shift when not fit to work.
- The driver became incapacitated between Lloyd Park tram stop and the approach to Sandilands curve and did not initiate braking at the expected point on the approach to the curve. The cause of the incapacitation is unknown, but could include loss of alertness as a result of fatigue, a medical event or condition.
- The level of functionality of the Driver's Safety Device was not sufficient to recognise that the driver was not fully vigilant.
- The system did not detect or control for excessive speed of trams.

Root Cause (2) – Incapacitation of driver

- The driver of the tram did not identify and act on braking cues in the approach to the Sandilands curve due to incapacitation.

- The system design does not provide adequate engineering controls for foreseeable human failures that could result from incapacitation.

Discounted theories

The following theories have been discounted based on balance of probability and consideration of known and indisputable facts:

- Obstruction on the infrastructure
- Failure of the infrastructure, control systems or tram.
- Malicious or deliberate act of the driver; Distraction of the driver from a mobile phone or radio.

Summary of Recommendations

The following recommendations are made with the following categorisation:

- **Primary (P)** – those that arose directly from the events leading to the incident (including the theories stated).
- **Secondary (S)** – those that have arisen from topics either relating indirectly to the incident or that would have affected the incident and resulting events (including the theories stated)
- **Observations (O)** – these are recommendations based on other areas that can be improved.

Reference	Recommendation	Description
R1 (P)	**Review available cues to the driver of the braking points and the approaching curve**	The investigation has highlighted that further cues could be added to the current infrastructure, as to the upcoming hazards (30m radius curve, junction) at Sandilands. A review should be conducted to consider upgrading the infrastructure cues available to the driver in order to maximise opportunity for the driver to predict suitable braking in advance of the curve.
R2 (S)	**Review the arrangements for the monitoring and management of speeding**	TOL should review how indicators in relation to the measurement of operational speed compliance are measured and reported and whether implementing leading indicators would give useful visibility of trends, increasing their ability to focus on areas of concern and take appropriate action. TfL/LT should maintain visibility of the implementation of monitoring and any controls that are identified as a result.

Reference	Recommendation	Description
R3 (P)	**Review of traction brake controller (TBC) driver's safety device (DSD) design**	Investigate the design limitations of the TBC, DSD and surrounding cab ergonomics in order to establish whether the TBC can be kept in the operating position by a driver who is "non-vigilant". Make recommendations to improve the design, or make additional controls, where this is seen to be reasonably practicable in line with obligations under the Health & Safety at Work etc. Act 1974 [R-10].
R4 (P)	**Review the arrangements for the monitoring and management of fatigue and fitness to work**	TOL should review how safety issues in the areas of fatigue and fitness to work are monitored in service, measured, reported and what indicators are used to monitor the success of controls in place. TOL should consider implementing leading indicators in areas where possible in order to gain suitable visibility from trends and increase their ability to refocus on areas of concern. TfL/LT should maintain visibility of the implementation of any additional controls and the results of monitoring undertaken.
R5 (S)	**Review route risk assessments and network risk model to reflect new understanding of risk arising from the Sandilands investigation**	It is recommended that LT and TOL review and update the Route Design Risk Assessment and Network Risk Model. As part of this review, LT and TOL should examine and document human factors risks and the controls put in place as a result of this investigation, identifying any additional mitigations required to reduce the risks associated with excess speed. Derailment scenarios should be benchmarked against those of rail operations to ensure all credible scenarios have been considered.
R6 (O)	**Review mechanisms used to promote Organisational Learning**	Both TOL and LT should further promote the use of confidential reporting systems and ensure that the outputs of these systems are used to support organisation learning. TOL and LT should further promote the near miss/incident reporting system in order to ensure that they are continuing to learn from incidents and near misses that occur within their organisation. TOL and LT should review the processes in place to capture, review, action and act on incidents and near misses in other organisations in order to learn from the lessons of failure in other systems.

Reference	Recommendation	Description
R7 (O)	**Review near miss reporting mechanisms**	LT should request a review of the TOL incident reporting process in order to determine whether the process is fit to be used to escalate a potential safety issue quickly to the appropriate owner within the business.
R8 (O)	**Consider feasibility of increasing containment of tram vehicles**	LT should consider the feasibility of increased containment of passengers from an overturn event at typical network speeds.

2 Contents

3 Glossary of Abbreviations and Acronyms

Term	Description
BT	Bombardier Transportation
BTP	British Transport Police
BTS	Blackpool Transport Services
CB	Circuit breaker
COG	Centre of Gravity
DSD	Driver's Safety Device
ECR	East Croydon Railway Stop
EOS	Enforcement and On-Street Operations
ERU	Emergency Response Unit
ETCS	European Train Control System
HSE	Health and Safety Executive
HMRI	Her Majesty's Railway Inspectorate
HSWA	Health & Safety at Work Act
LSTCC	London Streets Traffic Control Centre
LT	London Trams. The Infrastructure Manager (ROGS).
NR	Network Rail
OCC	Operations Control Centre
ORR	Office of Rail and Road
OTDR	On tram data recorder
PPI	Point Position Indicator
PSR	Permanent Speed Restriction
RAIB	Rail Accident Investigation Branch
ROGS	The Railways and Other Guided Transport Systems (Safety) Regulations 2006
ROTS	The Railways and Other Transport Systems (Approval of Works, Plant and Equipment). Regulations 1994
RSSB	Railway Safety & Standards Board
RTC	Risk Triggered Commentary
SMS	Safety Management System
SPAS	Signal Passed at Stop
TBC	Traction brake controller
TCL	Tramtrack Croydon Limited
TfL	Transport for London
TMS	Tram Management System
TOL	Tram Operations Ltd. The Transport Undertaking (ROGS).
TSR	Temporary Speed Restriction
USA	Urgent Safety Advice

4 Introduction

At about 06:07 hrs on Wednesday 9 November 2016, London Trams (LT) tram No 2551, travelling from New Addington to East Croydon, overturned on a 30m radius curved track with a Permanent Speed Restriction (PSR) of 20km/h, on the approach to Sandilands tramstop.

Of the 70 people on board, seven lost their lives and 62 people were injured (including the driver), 19 seriously. Tram No 2551 is a Bombardier CR4000 unit operated by Tram Operations Limited (TOL) on behalf of LT.

The overturned tram itself impacted an overhead electricity stanchion, lineside equipment cabinets as well as rails being stored nearby (see Figure 1 and Figure 2). Significant damage was sustained to both the tram and the adjacent infrastructure. Work is ongoing as a part of a separate workstream to investigate the performance of the tram structure during the overturn.

TOL, LT and Transport for London (TfL) implemented their respective emergency plans and responded to the incident. An independent investigation of the event was commissioned to determine its causes and the surrounding circumstance. Tram services East of Croydon were resumed at 12:30 on Friday 18 November.

This report describes the findings of this investigation. The findings from several workstreams are combined and presented using a causal analysis. This technique seeks to identify the main initiating event that led to the incident along with immediate and contributory causes of the incident, together with their root causes.

The report references sources (indicated for example by [R-1] etc.), where necessary.

4.1 Definitions

The below definitions were used in order to construct the root cause analysis of the causal chain, detailed in this report.

Initiating Event – the event that directly led to the incident in question (in this case, the tram overturning and striking infrastructure)

Immediate Cause – the cause that led directly to the initiating event happening.

Contributory Causes – these can be numerous and complex, as there can be several layers of potential controls that may have failed. Here we have included contributory causes that may have influenced the outcome, including controls that weren't designed to be present, but are present in other transport systems.

Root Causes – An agent, failure or fault from which a chain of effects or failures originates.

Figure 1 - Tram 2551 overview of resting position on adjacent tracks

Figure 2 - Tram 2551 roof against infrastructure

5 Terms of Reference

This investigation has been commissioned in order to:

- Record the events and state of the related systems before and after the incident
- Identify the causal chain including the initiating event, immediate causes, contributory and root causes.
- Recommend actions for TfL to consider to learn from the incident.

A review of the emergency response, handling and communication of all parties is to be undertaken by TfL and is out of the scope of this report.

6 Overview of network

6.1 Location

The London Tram network is shown in Figure 3 with the critical Lloyd Park to Sandilands section highlighted. It includes a long largely straight section of the former Woodside and South Croydon Railway.

The tramway passes through three consecutive separate tunnels approaching the curve at Sandilands. At each end of the straight former railway sections there are small radius curves providing connections to the newer tramway alignments, both of which have 20km/h speed limits (see Figure 3).

The track construction consists of S49 rail on Vortok fastened lightweight concrete sleepers and traction power is provided through the 750V DC overhead line equipment.

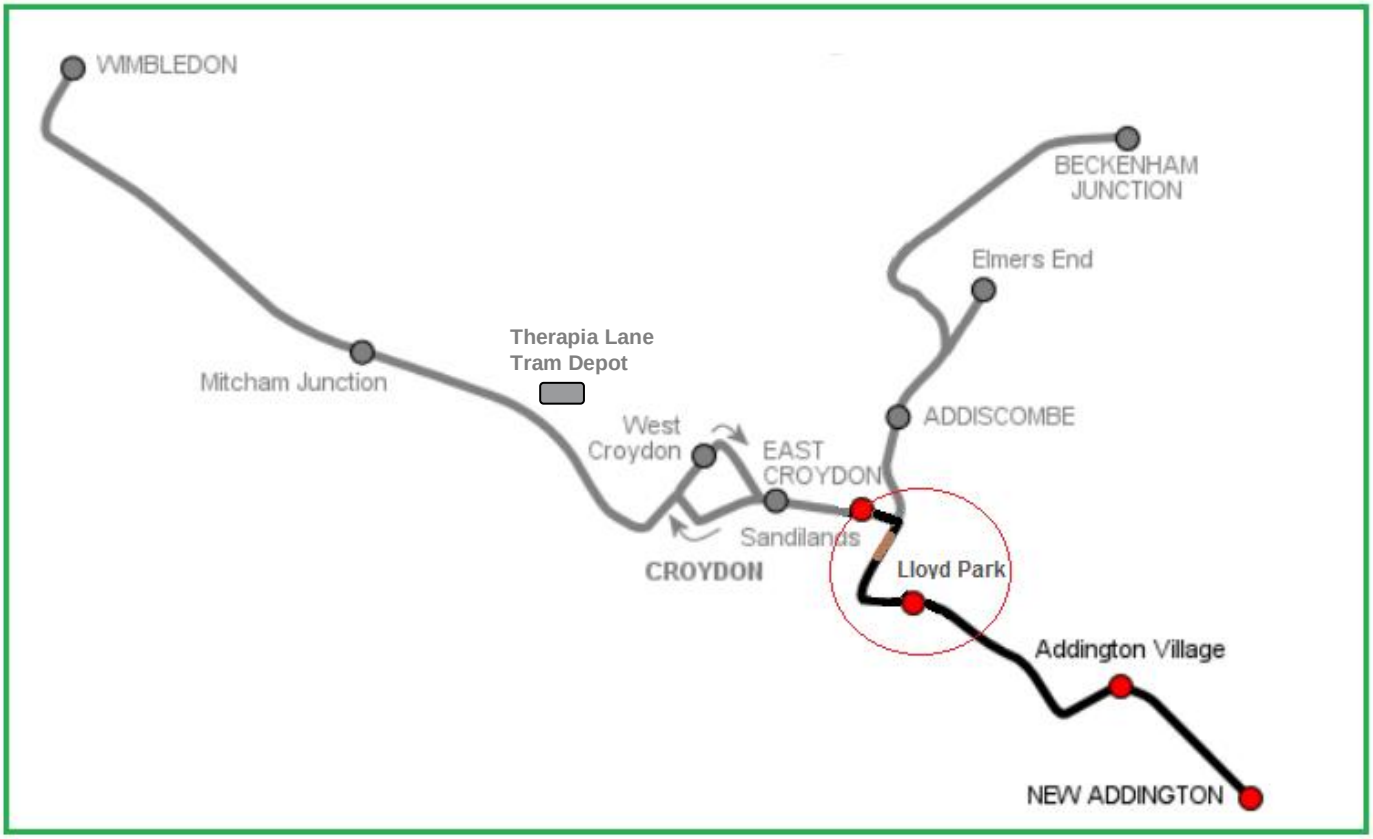


Figure 3 – LT Network highlighting Lloyd Park to Sandilands

6.2 Responsibilities

Under the current Operating Agreement (recorded in the 2007 contract) [R-4] TOL is responsible for the safe operation of the trams.

Since 2011 and 2014 respectively LT have assumed responsibility for the provision of infrastructure and trams maintenance from TOL.

The system was originally given authority to operate by HMRI [R-3]. The original submission to the HMRI was based on the applicable and current guidance for tramways at that time [R-7], using 'line of sight' principles, with specific conditions for application of signalling in areas segregated from street running.

A system running on line of sight is described as:

> *"a tram should be able stop before a reasonable visible stationary obstruction ahead from the intended speed of operation"* ([R-7] paragraph 22)

In parallel with the line of sight principles, safe operation also requires drivers to have knowledge of the route to anticipate key tasks, such as reducing speed in line with speed restrictions, signals and point position indicators. The driver also needs to know the location of traffic junctions, tram stops and pedestrian crossings.

The reliance on the driver as the principal mitigation for speed control on the system means that the Operator requires robust management of driver competence (including compliance with speed limits), as well as procedures to manage fitness to work and fatigue requirements.

7 Sequence of Events

7.1 Prior to Incident

On the morning of 9 November 2016, heavy rain was falling, it was dark and the temperature was around 4^{o} C.

The fleet of 30 trams required for the day's operation was available for service; both the infrastructure and trams were in serviceable condition.

Information associated with the driver's booking-on time has not, at this stage, been made available to this investigation and so is not included in this timeline.

By examining records (including 'loop' data) from the Operational Control Centre (OCC) and the On Tram Data Recorder (OTDR) data [R-2], the following timeline has been established:

- 05.16 Tram 2551 left the depot, having been prepared for service by the driver, and entered service at Therapia Lane, en route to New Addington.
- 05.46:57 The tram arrived at New Addington slightly ahead of the Working Timetable (WTT).
- 05.53:18 The driver, having changed cabs commenced his return journey. Tram 2551 was the fifth tram to depart New Addington that morning on Line 3 and called at each of King Henry's Drive, Fieldway, Addington Village, Gravel Hill, Coombe Lane tramstops in accordance with the WTT. The previous four trams did not exhibit any issues with maintaining the WTT.
- 06:02:27 Tram 2551 was stationary at Coombe Lane tramstop and departed Coombe Lane at 06:02:44 again in accordance with the WTT.
- 06:05:07 Tram 2551 arrived and was stationary at Lloyd Park tramstop departing Lloyd Park tramstop between 06:05:08 and 06:05:21 in accordance with the WTT.

This tramstop is the final stop prior to the point at which tram 2551 derailed, located approximately 1375 metres prior to the Sandilands curve.

7.2 During Incident

Appendix A includes a visual representation of the last 650 metres prior to the start of the curve to give a visual overview of the traction, braking and sanding applications along with the speed profile of the tram in relation to key features of the infrastructure such as the three tunnels, the inner portals between each tunnel and the location of the route signage. The relevant section of the diagram is replicated in Figure 4 (indicating the final 355 metres /15 seconds of the tram's movements)

By examining records (including 'loop' data) from the OCC and OTDR data, the following timeline has been established.

NOTE: All OTDR timing and distance are subject to validation by RAIB through its own investigation, the findings of which will be shared with this investigation when concluded.

NOTE: The traction and braking control on the tram has a speed control function. It is not possible from the OTDR data to determine whether the traction and braking were applied by the driver or the control system when maintaining a constant (or near to constant) speed.

- 06:05:21 Tram 2551 departed Lloyd Park tramstop, increasing speed steadily on the approach to the Coombe Road tunnel, reaching maximum line speed (80km/h) at 06:06:33.
- 06:06:34 Tram 2551 arrived at the entry point to Coombe Road tunnel travelling at 79km/h and continuing to take traction.
- 06:06:40 Tram 2551 passed through the inner portal between the Coombe Road tunnel and the Park Hill tunnel and maintained traction and travelling at 79km/h throughout until the inner portal between the Park Hill and Woodside tunnels.
- 06:06:46 [denoted "A" on diagram] Tram 2551 passed through the inner portal between the Park Hill tunnel and Woodside tunnel (approximately 330 metres from the curve), taking traction and travelling at around 79km/h. (It is understood that this is the location that drivers are trained to initiate braking in preparation for the speed reduction to 20km/h at the Sandilands Curve.) The tram continued into the Woodside tunnel and continued to take power.
- 06:06:52 [denoted "B" on diagram] The tram coasted then initiated braking at 06:06:52 for a period of less than one second travelling 13 metres before returning to coasting and travelling a further 9 metres. Tram is approximately 180 metres from the curve.
- 06:06:53 [denoted "C" on diagram] The tram took traction again, travelling a further 92 metres until 06:06:57 travelling at 78km/h. The tram then coasted for a further 12.5 metres before braking at 06:06:58, approximately 50-55 metres before the start of the curve.
- 06:06:58 [denoted "D" on diagram] The tram braked, with a rate of retardation in line with that of a normal service braking applied by the driver (around 1.3 ms^{-2}), with the sanding system being initiated (either automatically by the wheel slip/slide protection system, or manually by the driver) at 06:06:59 until 06:07:01.
- 06.07 [denoted "E" on diagram] TOL Control recorded that: "TMS generated an alarm that all Circuit Breakers (CB) between East Croydon Railway Stop (ECR) and Sandilands had tripped. Driver informed Control that he was in a bad state, the tram was on its side and several passengers were injured and he required help urgently." The Duty Manager called all emergency services and informed TOL and LT on-call managers.

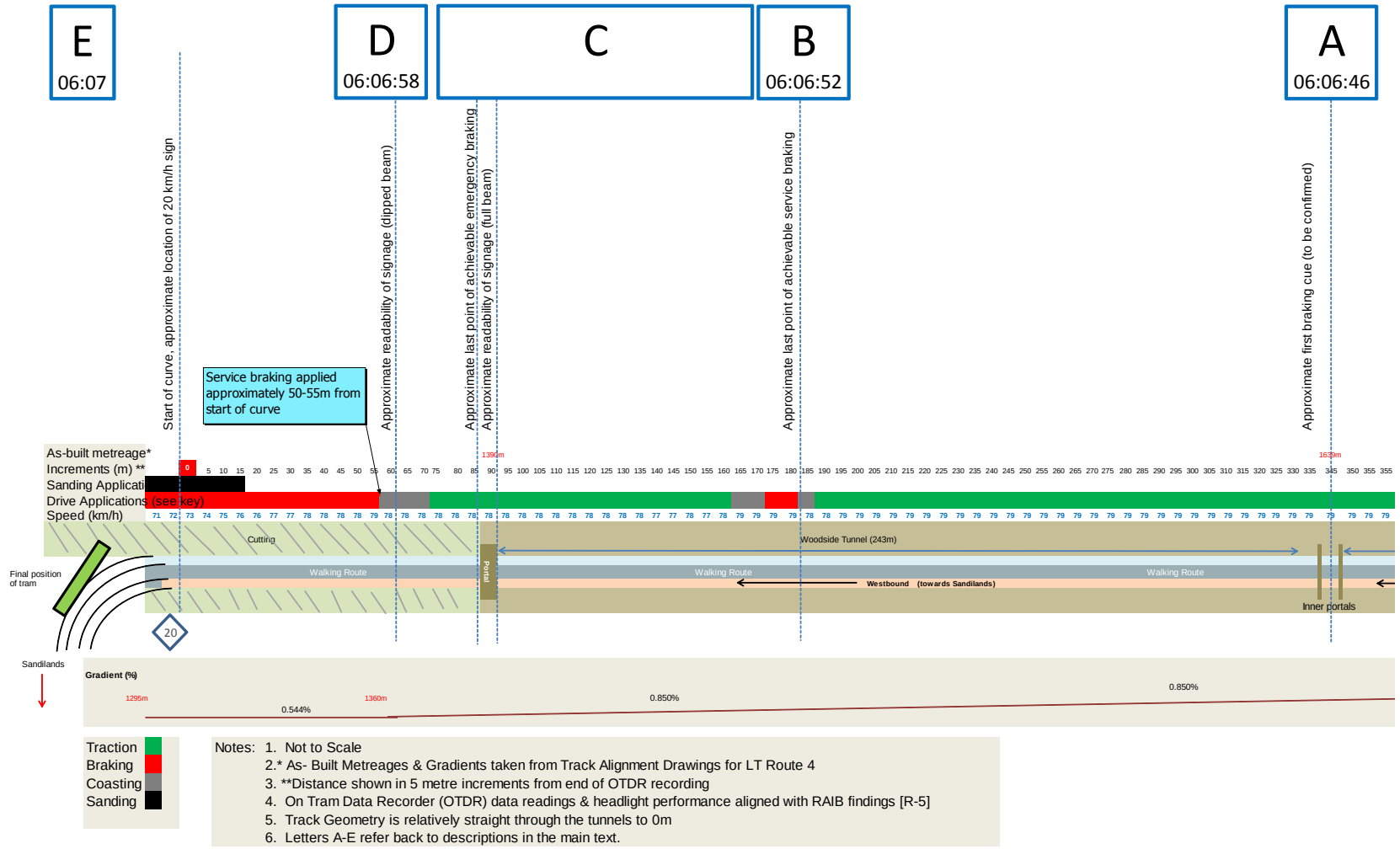


Figure 4 - Extract of Appendix A Sequence of events (schematic) over final15s/330m (approximation) before curve.

7.3 Post Incident

The following account is an abbreviated timeline of events immediately after the incident.

- 06.15 Director, London Trams received call from TOL Operations Director and passed on information to TfL on-call manager and progressively to others in TfL as appropriate.
- Initial reports indicated that the derailment was “in the Sandilands tunnel.” This was corrected when emergency services arrived
- 06.30 Emergency services and TOL Incident Officer were on site, by which time the Metropolitan Police were reporting fatalities. Area declared a crime scene. Driver arrested. Police took details from survivors.
- 06.36 TfL implemented its command and control structure in line with its emergency plan.
- 06:42 RAIB was notified via its telephone incident line, and deployed five inspectors and two support staff to the site of the incident.
- 07.07 Under the TfL emergency plan, TfL Managing Director of Surface Transport appointed Gold command, TfL Director at London Trams Silver, and Head of Road Space Management Sponsorship Silver. Bronze commanders appointed for London Streets Traffic Control Centre (LSTCC), Buses and Enforcement and On-Street operations (EOS).
- 07.36 HSE Senior Manager confirmed RAIB and ORR informed and estimated time of arrival on site of 08.30.
- 09.05 Switching implemented to de-energise and earth affected section.
- 09.30 Survivor/ bereaved welfare arrangements introduced. Buses used as shelter and to transfer injured to hospital.
- 10:02 The first three RAIB inspectors arrived on site. RAIB collection of OTDR.
- 12.00 51 survivors had been taken to hospital, 20 at St George’s Hospital (4 serious) and 31 to Croydon University Hospital (4 serious). 5 fatalities are known with suspicion of 2 more. Joint working and cooperation between all agencies. British Transport Police (BTP) in charge of site and moving into investigation phase following removal of casualties.
- 13.39 TfL Director of London Rail took over as Gold command.
- 15.25 Head of Health and Safety (Surface) confirmed commission of independent investigation.
- 16.32 RAIB issued a statement on the incident indicating that excessive speed was considered to be a factor.

7.4 Immediate actions taken to resume operations

TfL established an oversight panel of Senior Managers to direct and review assurance in respect to resumption of services east of Croydon. LT and TOL implemented the following actions, which enabled operations to restart on Friday 18th November 2016.

7.4.1 Urgent Safety Advice

On 14th November 2016, RAIB issued an Urgent Safety Advice (USA) notice to LT and TOL, requiring them to reduce the risk of trams approaching the Sandilands junction from New Addington at excessive speed before restart of service. LT introduced new Temporary Speed Restrictions, including new signage and driver briefings (by TOL) on this advice.

7.4.2 Peer Review

In order to review the adequacy of the actions taken to resume services east of Croydon, LT also sought peer review from the UK tram trade body, UKTram, who on 16th November 2016, recommended increasing speed monitoring controls upon restart of operations, and that consideration of illuminated speed triggered detection signs and corner chevron markers should be given in the near future.

7.5 Subsequent work

The following work has been implemented on the system since the reinstatement of services, which address some of the recommendations included within this investigation report.

- Retroreflective chevrons have been added to a number of locations across the tramway, including the 30m radius Sandilands curve infrastructure
- TOL have increased speed checks across the network
- Speed activated warning signage is being trialled at a number of locations across the tramway including the approach to the Sandilands curve.

8 Investigation of Causal Factors

8.1 Methodology

The investigations into the tram derailment on 9 November 2016 are ongoing and the complete set of contributory factors are still to be fully determined as the findings and knowledge are made available from:

- BTP
- TOL
- the ongoing RAIB investigation.

A series of surveys, interviews, workshops and documentation reviews were carried out in order to determine the initiating event for the tram derailment, and to establish the immediate and contributory causes. From these, the root causes were drawn. The key areas reviewed covered:

- Infrastructure
- Rolling Stock
- Safety and Operations management
- Human Factors

This investigation has not had access to the tram driver or his records and has had no opportunity to interview him.

9 Overview Diagram – Causal Chain

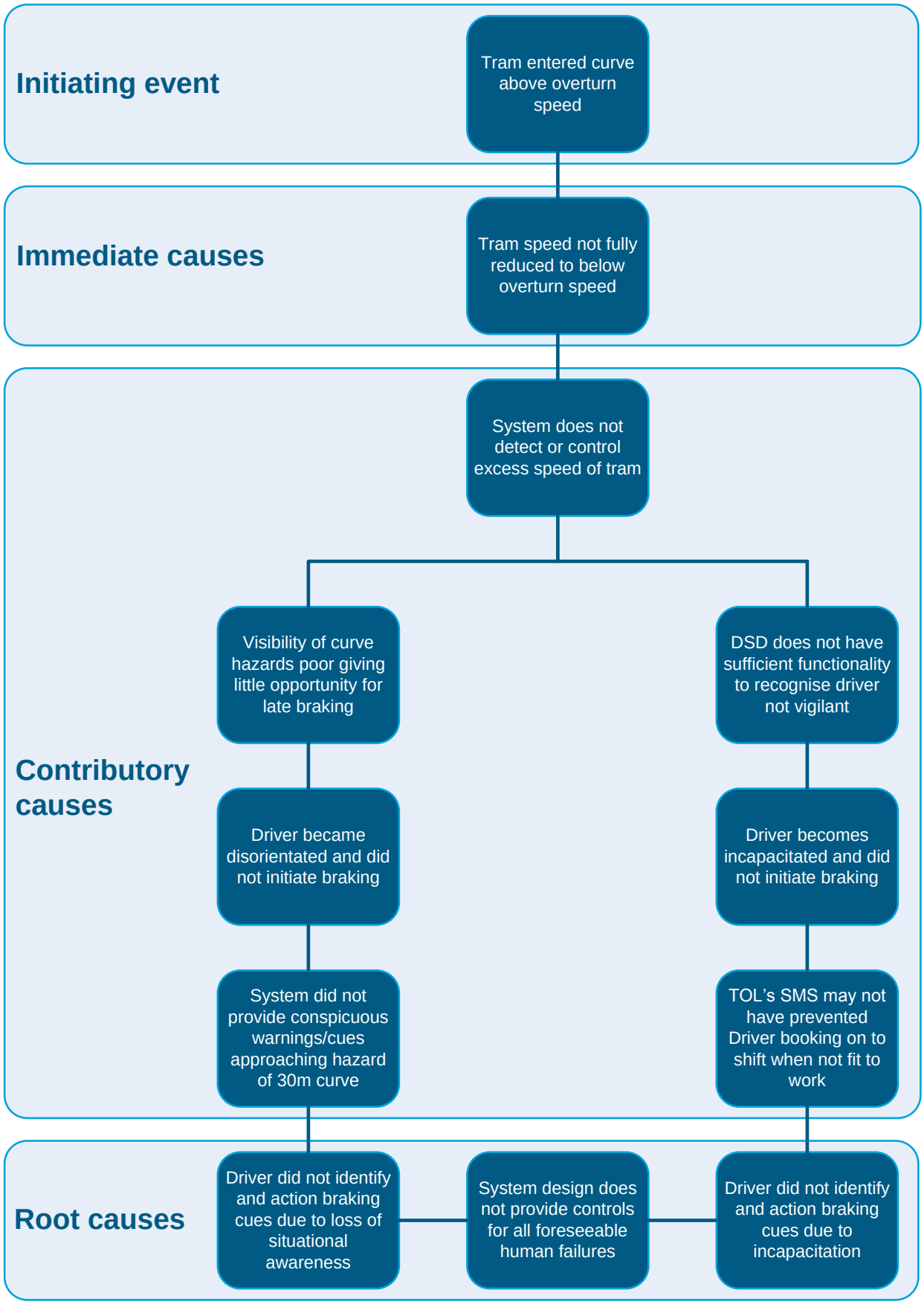


Figure 5 - Overview of Causal Chain

10 Overview

The causal chain (see Figure 5) described as two possible contributory chains. Completion of investigations may enable one to be eliminated or identified as more probable than the other, to confirm one as the most likely causal chain. This report describes the initiating event and immediate cause as shared conclusions, and then discusses both the probable contributory and associated root causes in turn.

11 Initiating event

11.1 Conclusion

The event that initiated the derailment was tram 2551 entering the Sandilands curve at approximately 73 km/h, significantly above the 20 km/h PSR in place. This resulted in the tram losing contact with the rails, overturning, striking several items of infrastructure and coming to rest on its right hand side.

11.2 Discounted

The investigation to date has discounted the following, through site survey, infrastructure surveys as well as checks and testing of the tram systems.

- The presence of any obstruction on the infrastructure
- Failure of the infrastructure
- Failure of the tram system.

The surveys and testing did not identify anything relating to the condition of the tram or infrastructure which could have initiated the derailment.

12 Immediate Cause

12.1 Conclusion

The tram entered the curve in excess of the PSR as a result of neither the service braking nor the emergency brake being initiated by the driver in time to reduce the tram to below the tram overturn speed. The overturn speed is the speed at which the tram would overturn, based on its Centre of Gravity (COG) and the radius and cant of the track curve that it is entering. The overturning speed of the tram is estimated to be between 45km/h and 52km/h, depending on the loading on the day. A normal level of service braking was initiated by the driver approximately 2.5 seconds before the start of the curve [R-5], which equates to around 50-55m before the 20km/h sign at the curve. This is later than the trained point to commence braking and also later than the last point at which the service or emergency brake could achieve the required deceleration before the Sandilands curve.

12.2 Discounted

The investigation to date has discounted the following, through testing of the tram systems and study of the OTDR data.

- Failure of the tram braking system and controls
- Malicious act of the driver.

The testing did not identify anything relating to the condition of the tram braking system and controls which could have led to the failure of the tram to brake sufficiently on the approach to the curve.

The reported actions of the driver are concluded to be inconsistent with a deliberate act to overturn the tram by the driver.

13 Contributory & Root Causes

The conclusions below are based on two main theories, either of which is considered to be a viable option:

1. “Loss of situational awareness”, and
2. “Driver incapacitation”.

The order in which they are presented gives no indication as to which is considered the most likely at this stage.

13.1 Contributory Causes (1) – Loss of situational awareness

Situational awareness is the state where a person is aware of where they have been, where they are now where they are supposed to be next. It also informs the person of anyone or anything that is a threat to their health [R-8]. The awareness comes from a number of factors, including knowledge, experience and education. Because of this, a person’s situational awareness is individual, and potentially different to those around them.

A person’s situational awareness is only as accurate as their own perception of the situation. What the person is thinking is their situation may not accurately reflect reality. How someone interprets a situation will rely on several factors including the type and quality of the information presented and their past experiences, as well other factors that may diminish their ability to rationalise information, such as fatigue or distraction.

Temporary loss of and lack of situational awareness is well recognised in multiple industries, such as fire fighting, policing, air traffic control, aviation, ship navigation as well as for simpler activities such as driving a car or riding a bicycle. Its contribution in accidents is well documented, and has been cited as a causal factor of many accidents by investigations [B-12][R-8]. Guidance on managing situational awareness is published and available in many industries, including UK mainline rail (RSSB) and the Health and Safety Executive (HSE).

In this causal chain, the driver did not anticipate the presence of the upcoming curve and therefore the necessary braking required in advance of entering the curve, due to a temporary loss of awareness of his position (and the subsequent braking activities required at that point). It is concluded from OTDR data [R-2], that this error state would have occurred after the preceding tram stop at Lloyd Park where the driver appeared to be attentive to the required driving activities less than 2 minutes before.

13.1.1 Background

Hazards

There are two hazards which require the control of speed into the Sandilands curve:

- The presence of a curve of approximately 30m radius on the route, and the combined centre of gravity of the tram was such that an approach speed of (estimated) 45-52km/h would cause the tram to overturn. The curve was therefore allocated with a 20km/h PSR to provide a large safety factor against this hazard. The track is also canted to mitigate the effects of the overturn forces.
- Signal SNJ07S is situated on the curve, within the 20km/h PSR zone; this signal exists to protect against a conflict with the converging line at Sandilands Junction at the west end of the curve. Failure to control speed on the approach to this signal increases the likelihood of a Signal Passed at Stop (SPAS) with potential for collision if the signal overlap distance is exceeded.

Signage and cues

The system design did not include any additional aids to drivers to make them aware/remind them that there was an upcoming speed step down requirement prior to the curve and associated (20km/h) PSR. This was controlled operationally through training and route knowledge accumulated through experience. The braking required to successfully bring the tram from the linespeed through the tunnels (80 km/h) to the PSR (20km/h) needs to be initiated well in advance of the curve, understood to be usually initiated within the final (Woodside) tunnel, around 330m before the start of the curve. The last point of achievable service braking is around 180m before the start of the curve [R-5]. The curve beyond the tunnel exit and its 20km/h PSR sign would be extremely difficult to detect by the driver at this point under the conditions experienced on the 9th November 2016 [R-5] (see Appendix A - Final sequence of events).

The signs are standard across the tramway, they comply with current guidance [R-9] and those at Sandilands Junction at the time of the incident were clean and in good condition.

The reflective signage indicating the 20km/h PSR is readable (i.e. the numerals can be read) on a clear night, from the driving position of a tram driven at caution, from a distance of around 60m (dipped beam) and 90m (on full beam) [R-5]. This figure could be reduced by heavy rain, such as that experienced on the morning of the incident [R-5]. The ability of the driver to detect the signage will also be influenced by the tram speed, the driver's visual acuity, the local lighting as well as any other tasks that the driver was undertaking. See Figure 6 below.

Figure 6 - 20km/h board on exit from Woodside tunnel (photo taken around 85m from the start of the curve)

Figure 7 - 20 km/h PSR board on 30m radius curve, with the entrance to the Elmers End/Beckenham Junction branch line showing opposite

The incident has highlighted that there is no relevant signage that can be sighted from the required start of braking. Knowledge of the route and the next maximum permissible speed is therefore required and the ability to successfully complete this task is dependent on the driver correctly identifying the point for the start of braking.

The braking cue point (nominally towards the start of the Woodside tunnel, see Appendix A and Figure 4 for details), can be ambiguous in certain environmental conditions and is therefore a contributory factor to this theoretical causal chain (see section on human factors below)

The Regulator at the time of commissioning the tramway (HMRI) did not provide any clear guidance on signage layout principles in this area.

Risk Assessment

The original system risk assessment did not explicitly consider all the foreseeable failures from human error (e.g. incapacitation, loss of situational awareness, distraction etc) and the risks presented should tram speed not be adequately controlled.

Whilst the risk assessment identified derailment risk, it did not include subsequent factors such as overturning or striking infrastructure/objects.

It was assumed that a competent driver would always comply with the 20km/h PSR. It is not current practice on tram systems to use engineering controls to control or supervise vehicle movements. Such controls have been progressively introduced to the mainline railway over the last few decades and are now routine. UK light rail systems are operated on “Line of Sight” meaning that the driver is fully responsible for controlling the train at all times. Operational controls are used to manage risks associated with driver failure/error by seeking to ensure that the drivers are alert and competent.

Human Factors

This theory assumes the driver makes a mistake in the interpretation of his location on the route. This could feasibly include a mistake in:

1. Perceived progression along the tunnel(s)
2. Perceived direction of movement within the tunnel(s).

The tunnel is the third in a series of three consecutive tunnels, separated only by a small gap between structures. The driver would need to correctly identify the start of the Woodside tunnel to correctly initiate the braking task. It is considered that the start of the third tunnel may be difficult to locate in some conditions, such as darkness.

The tunnel lighting is designed to be symmetrical, with lighting at each end of the tunnel being more brightly lit than the centre section, so might lead to driver disorientation due to the environment appearing similar in both directions. At the time of the accident, some of this lighting was not illuminated, making the lighting at each end of the tunnel differ slightly. It is not considered that this difference was sufficient to give any strong cue to the driver of his direction of travel.

Other interpretations of this theory include a situation where the driver undergoes other types of human error, of either a “slip” or a ”lapse”, thus omitting the braking task within the tunnel when heading towards the curve in question.

Whilst not a direct link in the theory relating to loss of situation awareness, fatigue and other medical issues can affect the performance of the driver in the collection, interpretation and actioning of information and cannot be discounted yet as being contributory causes. Information on the fitness of the driver and relevant historical information is not currently available to this investigation.

13.1.2 Conclusions

- The system does not provide conspicuous warning/cues to the driver on where to brake the tram on the approach to the hazards of the 30m radius curve and junction at Sandilands. A significant amount of braking is required to ensure that the tram speed is reduced from the 80 km/h linespeed to below the tram overturn speed, and is controlled through a 20 km/h PSR on the curve.
- Under this theory, the driver became disorientated as to the location and/or direction of travel between Lloyd Park and approach to Sandilands curve and did not initiate braking at the expected/required point on the approach to the curve.
- Visibility of the Sandilands curve, speed restriction signage and signal SNJ07S is achievable after the required point of first braking. Later sighting of the curve and signage offers little opportunity for the driver to recover from earlier failure to reduce the speed of the tram.
- The system did not detect or control excessive speed of trams.

It is also noted that factors noted below in “incapacitation of driver” (section 13.3) would reduce the driver’s ability to maintain situational awareness and would play a part in this causal chain.

13.1.3 Discounted

The following theories were discounted based on the evidence known about the driver, a site survey of the site and infrastructure, and discussions with the Infrastructure Managers.

- Any deficit in competence of the driver to undertake the braking activity required
- Any distractions from mobile phone or cab radio away from the braking activity required.

13.1.4 Recommendations

Reference R1	Review available cues to the driver of the braking points and the approaching curve
Recommendation	The investigation has highlighted that further cues could be added to the current infrastructure, as to the upcoming hazards (30m radius curve, junction) at Sandilands. A review should be conducted to consider upgrading the infrastructure cues available to the driver in order to maximise opportunity for the driver to predict suitable braking in advance of the curve.
Background	The review should consider: • How the risk from directional disorientation can be managed by the use of intermediate speed step downs between significantly different PSRs. • Highlighting the presence of the curve itself by use of retro reflective chevrons. • Whether any risks associated with the transition to/from lit tunnels to the wider infrastructure are mitigated by the current design and condition. • The medical standards used for visual acuity of driver and use this to assess suitability against any implemented controls. The risks and controls discussed above should be considered for each location on the Croydon Tram network where similar hazards may exist.

Reference R2	Review the arrangements for the monitoring and management of speeding
Recommendation	TOL should review how indicators in relation to the measurement of operational speed compliance are measured and reported and whether implementing leading indicators would give useful visibility of trends, increasing their ability to focus on areas of concern and take appropriate action. TfL/LT should maintain visibility of the implementation of monitoring and any controls that are identified as a result.

Reference R2	Review the arrangements for the monitoring and management of speeding
Background	Speed management is a vital constituent part of running a safe tramway system. • TOL should develop and document an effective system to monitor compliance with speed limits, and ensure that they adjust their recruitment, training, and procedures as necessary in order to increase levels of compliance and reporting. This system could include unobserved arrangements (for instance through review of OTDR data or by running automated reviews of loop data if this could yield a suitable level of analysis). • The review should include how driver training addresses anticipation of speed restrictions, braking cues etc. • TOL should investigate the use of Risk Triggered Commentary (RTC) and consider whether using RTC could be used to enhance situation awareness in certain locations.

13.2 Root Cause 1 – Loss of situational awareness

13.2.1 Conclusion

- The driver of the tram did not identify the need to brake the tram in the approach to the Sandilands curve due to a temporary loss of situational awareness.
- The system design does not provide adequate engineering controls for all foreseeable human failures that could result in a temporary loss of or lack of situational awareness.

13.3 Contributory Causes (2) – Incapacitation of driver

13.3.1 Background

In this context, incapacitation can be thought of as a continuum, which can extend at one end, from “no incapacitation” through small loss of alertness/attention (perhaps due to tiredness or distraction), and through more serious incapacitation, where an individual is unable to function normally (for instance, during a stroke), and extending to complete physical and mental incapacitation (for instance, being unconscious as a result of a heart attack, or in a deep sleep).

This causal chain states that the driver may have been incapacitated enough to be unable to initiate braking or attend to the braking task. This incapacitation would have been temporary as the driver is known to have reacted to the overturned tram and called for assistance.

Operational controls are used by TOL to ensure that the driver is fit to work. This includes screening for use of drugs and alcohol, planning supervising and management of work/rest patterns for all drivers, as well as providing supervision of any medical issues that the driver may be experiencing.

Incapacitation through alcohol, drugs and medical conditions are easily checked after an incident, however personal fatigue is more difficult to objectively quantify. Therefore, a review was undertaken of the fatigue controls in place in TOL.

It was found that TOL had identified fatigue in their risk assessments and implemented a Management of Fatigue policy in the business. However, the associated procedures and supporting processes relating to the policy within the business missed opportunities to raise awareness and manage fatigue at a working level.

TOL did not measure fatigue management controls at Executive level and, because of this, it would have been extremely difficult for TOL Executive or TfL to have had a good level of visibility of any arising issues in this area.

If this theory is the correct causal chain leading to the accident (that the driver became incapacitated), the Driver's Safety Device (DSD) could have been expected to intervene. The DSD requires the driver to maintain a force onto the Traction Brake Controller (TBC) at all times. If this force is not maintained then an audible alarm is sounded to alert the driver, and if the force is not re-applied within a period of four seconds, the emergency brakes are automatically initiated to stop the tram. The DSD did not operate in this instance.

It may be possible to maintain a force on the DSD whilst being incapacitated in certain circumstances, and a vigilance device (where the system monitors movement inputs of the driver) may give a better indication of the attention of the driver.

From review of the OTDR it was found that any incapacitation occurred after the preceding tram stop at Lloyd Park, as the driver was able to perform driving tasks prior to this point (less than 2 minutes prior to the derailment).

Refer to the discussion in 13.1.1 (under 'Risk assessment') regarding the use of speed monitoring on light rail.

13.3.2 Conclusions

- The Driver Management systems may not have prevented the driver booking onto his shift when not fit to work.
- The driver became incapacitated between Lloyd Park tram stop and the approach to Sandilands curve, preventing him from initiating braking at the expected point on the approach to the curve. The cause of the incapacitation is unknown, but could include loss of alertness as a result of fatigue, a medical event or condition.
- The level of functionality of the DSD was not sufficient to recognise that the driver was not fully vigilant.
- The system did not detect or control excessive speed of trams.

13.3.3 Discounted

The investigation to date has discounted the following, through testing of the tram systems and study of the OTDR.

- Failure of the DSD to activate emergency braking.

This means that the DSD was not triggered by loss of driver interface; a force was maintained by the driver on the TBC, suitable to sustain the DSD, throughout the approach to the Sandilands curve.

13.3.4 Recommendations

Reference R3	Review of traction brake controller (TBC) driver's safety device (DSD) design
Recommendation	Investigate the design limitations of the TBC, DSD and surrounding cab ergonomics in order to establish whether the TBC can be kept in the operating position by a driver who is "non-vigilant". Make recommendations to improve the design, or make additional controls, where this is seen to be reasonably practicable in line with obligations under the Health & Safety at Work etc. Act 1974 [R-10].

Reference R3	Review of traction brake controller (TBC) driver's safety device (DSD) design
Background	The HMRI guidance at the time of approval [R-7] that is still in place [R-9] states: *"299 The following should be provided:* *(a) a traction and brake controller, which incorporates a hazard braking position (it may also incorporate a driver's safety device);* *(b) a driver's safety device, designed so that it cannot be kept in the operating position other than by a vigilant tram driver;"*

Reference R4	Review the arrangements for the monitoring and management of fatigue and fitness to work
Recommendation	TOL should review how safety issues in the areas of fatigue and fitness to work are monitored in service, measured, reported and what indicators are used to monitor the success of controls in place. TOL should consider implementing leading indicators in areas where possible in order to gain suitable visibility from trends and increase their ability to refocus on areas of concern. TfL/LT should maintain visibility of the implementation of any additional controls and the results of monitoring undertaken.
Background	Driver management is a vital constituent part of running a safe tramway system, particularly where a major control for many risks to the driving task is the competency and alertness of the driver. The review should consider: • The technologies available to supplement the existing operational controls. • Whether daily fitness for work is a self declaration or is supported by observation of individuals by supervisory staff. • The actions expected of individuals if they feel fatigued and/or unfit for duty, or become so whilst on shift. • How the importance of fatigue and fitness management is reinforced to TOL employees beyond their initial employment and associated induction process; whether TOL's fitness management arrangements materially changed since previous audits. • Whether any TOL staff policies could influence behaviour of staff to report to work in an unfit or potentially unfit condition. • The role played by confidential reporting systems.

13.4 Root Cause – Incapacitation of driver

- The driver of the tram did not identify and act on braking cues in the approach to the Sandilands curve due to incapacitation.
- The system design does not provide adequate engineering controls for foreseeable human failures that could result from incapacitation.

13.5 Risk Assessment

13.5.1 Background

LT manage an extensive Network risk model which is used to prioritise risk management activities.

When the original risk assessment was conducted, the risk from derailment was considered based on historical incidents at other light rail systems. In the last 50 years, instances of high speed derailments where the vehicle has overturned on a light rail system are extremely rare. Additional risk assessments are owned and managed by TOL.

13.5.2 Conclusion

The risk assessment considering the potential for derailment did not consider overturning at speed or striking infrastructure/other lineside objects.

13.5.3 Recommendation

Reference R5	Review route risk assessments and network risk model to reflect new understanding of risk arising from the Sandilands investigation
Recommendation	It is recommended that LT and TOL review and update the Route Design Risk Assessment and Network Risk Model. As part of this review, LT and TOL should examine and document human factors risks and the controls put in place as a result of this investigation, identifying any additional mitigations required to reduce the risks associated with excess speed. Derailment scenarios should be benchmarked against those of rail operations to ensure all credible scenarios have been considered.
Background	The risk assessments did not fully consider the scenarios of: • Human behaviour resulting in a failure to comply with speed limits • A tram overturning following a derailment • A tram striking an object following a derailment It remains necessary for both LT and TOL to have appropriate risk assessments for their areas of responsibility and to cooperate for those areas where risks require joint management. These are obligations defined within the HSWA [R-10], and ROGS [R-6].

14 Observations

14.1 Speeding & fatigue management

14.1.1 Background

A review of incidents involving speeding and derailment on curves was conducted in order to identify other human failures in this type of situation. The findings of this review are outlined in Appendix B. Notably, a previous report of speeding on the network, initiated on the 31 October 2016, at the Sandilands curve, had not been processed at the time of the derailment. The timely investigation of this near miss, may have affected the outcome of this incident. This and other incidents of speeding and other human failures, demonstrate the risks that are presented when the human driver fails.

In addition to the formal reporting outlined, reported instances of fatigued drivers on the network have been circulated on social media.

14.1.2 Conclusion

Safety related near miss reporting should be able to be cascaded and acted on quickly within the organisation.

14.1.3 Recommendations

Reference R6	Review mechanisms used to promote Organisational Learning
Recommendation	Both TOL and LT should further promote the use of confidential reporting systems and ensure that the outputs of these systems are used to support organisation learning. TOL and LT should further promote the near miss/incident reporting system in order to ensure that they are continuing to learn from incidents and near misses that occur within their organisation. TOL and LT should review the processes in place to capture, review, action and act on incidents and near misses in other organisations in order to learn from the lessons of failure in other systems.
Background	The use of near miss, incident and confidential reporting systems enables organisations to gain visibility of possible blind spots in their safety management systems. Considering incidents and near misses within other transport systems will enable applicable lessons from other organisations to be identified.

Reference R7	Review near miss reporting mechanisms
Recommendation	LT should request a review of the TOL incident reporting process in order to determine whether the process is fit to be used to escalate a potential safety issue quickly to the appropriate owner within the business.
Background	The near miss event that occurred on 31 October 2016 did not get escalated quickly enough within the TOL and LT organisations during the 8 intervening days to assist in any relevant interventions.

14.2 Containment

14.2.1 Background

The structural integrity of a vehicle provides protection for those travelling in the vehicle.

The incident has highlighted that whilst the structural integrity of the tram remained intact, the integrity of the windows and doors was compromised when it experienced the overturn event at speed.

Whilst the details of the passenger injury mechanisms are still to be confirmed, it can be concluded that in a number of cases, loss of separation between the inside and the outside of the tram was a contributory factor to the severity of the injuries sustained by the passengers.

Initial review of the window and door systems has concluded that the design is compliant with standards, and performed as the design intended during the incident.

14.2.2 Conclusion

Whilst the design of the tram is as expected and consistent with practices elsewhere in UK light rail and bus systems, there is opportunity to consider implementing increased containment measures for trams within the light rail operating environment. This approach has been implemented in mainline railways in recent years as a result of several incidents where containment of passengers had been identified as an issue.

The impact of any such measures on other road users must be fully assessed, for example the impact of any increase in weight on braking distances and the consequences of collision with other vehicles and pedestrians.

14.2.3 Recommendation

Reference R8	Consider feasibility of increasing containment of tram vehicles
Recommendation	LT should consider the feasibility of increased containment of passengers from an overturn event at typical network speeds.
Background	The overturn event highlighted that the structural integrity of the tram was heavily compromised during the incident, leading to several fatalities and many injuries.

15 Summary of Recommendations

The following recommendations are made with the following categorisation:

- **Primary (P)** – those that arose directly from the events leading to the incident (including the theories stated).
- **Secondary (S)** – those that have arisen from topics either relating indirectly to the incident or that would have affected the incident and resulting events (including the theories stated)

Where the recommendations relate to a particular theory, this is stated.

- **Observations (O)** – these are recommendations based on other areas that can be improved.

Reference	Recommendation	Description
R1 (P)	**Review available cues to the driver of the braking points and the approaching curve**	The investigation has highlighted that further cues could be added to the current infrastructure, as to the upcoming hazards (30m radius curve, junction) at Sandilands. A review should be conducted to consider upgrading the infrastructure cues available to the driver in order to maximise opportunity for the driver to predict suitable braking in advance of the curve.
R2 (S)	**Review the arrangements for the monitoring and management of speeding**	TOL should review how indicators in relation to the measurement of operational speed compliance are measured and reported and whether implementing leading indicators would give useful visibility of trends, increasing their ability to focus on areas of concern and take appropriate action. TfL/LT should maintain visibility of the implementation of monitoring and any controls that are identified as a result.
R3 (P)	**Review of traction brake controller (TBC) driver's safety device (DSD) design**	Investigate the design limitations of the TBC, DSD and surrounding cab ergonomics in order to establish whether the TBC can be kept in the operating position by a driver who is "non-vigilant". Make recommendations to improve the design, or make additional controls, where this is seen to be reasonably practicable in line with obligations under the Health & Safety at Work etc. Act 1974 [R-10].

Reference	Recommendation	Description
R4 (P)	**Review the arrangements for the monitoring and management of fatigue and fitness to work**	TOL should review how safety issues in the areas of fatigue and fitness to work are monitored in service, measured, reported and what indicators are used to monitor the success of controls in place. TOL should consider implementing leading indicators in areas where possible in order to gain suitable visibility from trends and increase their ability to refocus on areas of concern. TfL/LT should maintain visibility of the implementation of any additional controls and the results of monitoring undertaken.
R5 (S)	**Review route risk assessments and network risk model to reflect new understanding of risk arising from the Sandilands investigation**	It is recommended that LT and TOL review and update the Route Design Risk Assessment and Network Risk Model. As part of this review, LT and TOL should examine and document human factors risks and the controls put in place as a result of this investigation, identifying any additional mitigations required to reduce the risks associated with excess speed. Derailment scenarios should be benchmarked against those of rail operations to ensure all credible scenarios have been considered.
R6 (O)	**Review mechanisms used to promote Organisational Learning**	Both TOL and LT should further promote the use of confidential reporting systems and ensure that the outputs of these systems are used to support organisation learning. TOL and LT should further promote the near miss/incident reporting system in order to ensure that they are continuing to learn from incidents and near misses that occur within their organisation. TOL and LT should review the processes in place to capture, review, action and act on incidents and near misses in other organisations in order to learn from the lessons of failure in other systems.
R7 (O)	**Review near miss reporting mechanisms**	LT should request a review of the TOL incident reporting process in order to determine whether the process is fit to be used to escalate a potential safety issue quickly to the appropriate owner within the business.
R8 (O)	**Consider feasibility of increasing containment of tram vehicles**	LT should consider the feasibility of increased containment of passengers from an overturn event at typical network speeds.

16 List of References

[R-1] Terms of Reference provided to SNC-Lavalin on 24th November 2016. Amended 10th January 2017

[R-2] OTDR data file

[R-3] HMRI Authority to Operate, 19th May 2000

[R-4] Operating Agreement, TfL

[R-5] Rail Accident Investigation: Interim Report 2, February 2017, Fatal accident involving the derailment of a tram at Sandilands Junction, Croydon 9th November 2016. January 2017, RAIB

[R-6] The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS)

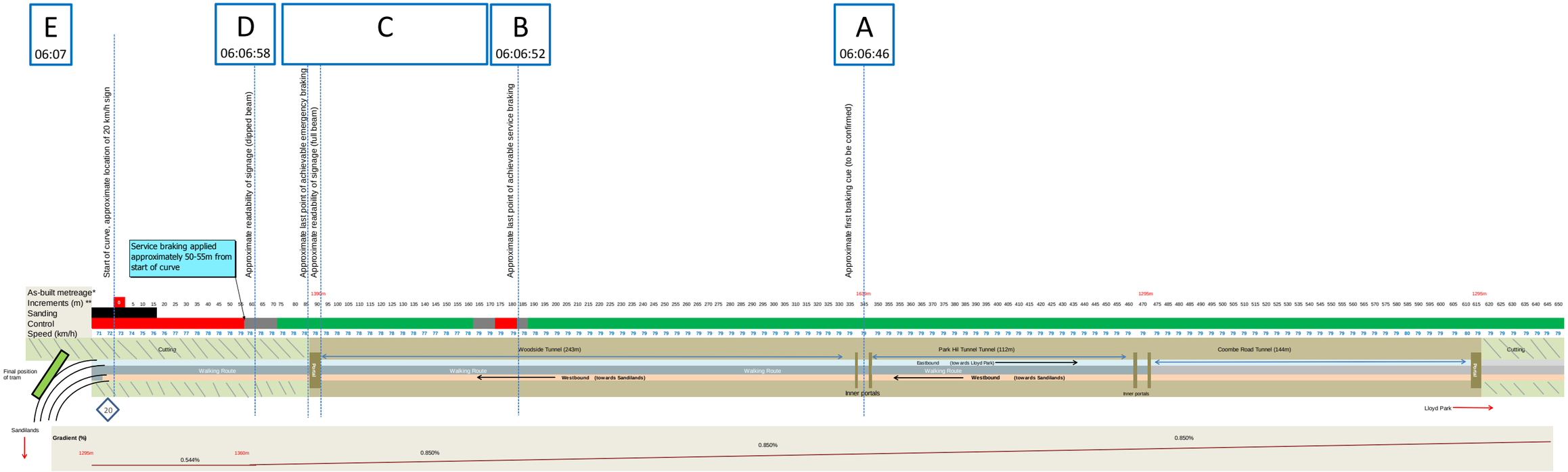
[R-7] Railway Principles and Guidance, Part 2, Section G – Tramways, 1997, HMRI

[R-8] http://www.hse.gov.uk/construction/lwit/assets/downloads/situational-awareness.pdf

[R-9] Railway Safety Publication 2, Guidance on Tramways, ORR, 2006

[R-10] Health & Safety at Work Act, 1974

Appendix A Final sequence of events



Traction	
Braking	
Coasting	
Sanding	

Notes:
1. Not to Scale
2. * As- Built Metreages & Gradients taken from Track Alignment Drawings for LT Route 4
3. **Distance shown in 5 metre increments from end of OTDR recording
4. On Tram Data Recorder (OTDR) data readings & headlight performance aligned with RAIB findings [R-5]
5. Track Geometry is relatively straight through the tunnels to 0m
6. Letters A-E refer back to descriptions in the main text.

Appendix B Review of Previous Incidents

The following review of previous speeding related incidents on the Croydon system, other light rail systems and mainline rail was undertaken. The review highlighted the potential for human failure, and how speed and control of the tram could be compromised by errors made by the driver, including loss of situational awareness.

The reported speeding on the Croydon system is also noted as a potential near miss report, that did not receive attention in time to affect the events of 9 November 2016.

Management of speeding incidents by TOL

It is understood that there have been 3 instances of formal driver disciplinary action for speeding in the last 5 years.

Reported over speeding - 31st October 2016 [B-1]

In addition to the speeding incidents above, a report was made to TfL Customer Services of an over speeding incident on the Tram network on the 31st October via email on the day of the incident. TOL responded to the email on the 2nd November indicating that they would conduct an investigation to identify the tram and the driver.

TfL did not receive any information regarding this event in the time between its initial reporting and the incident on the 9th November [B-10]. All events are recorded in a daily incident record, and shared with TfL on a periodic basis.

Manchester Metrolink - June 2016 [B-2]

A Metrolink tram is reported to have taken a 10mph curve at 28mph, causing the passengers to be thrown from their seats and causing minor injuries to three passengers. The driver is alleged to have not reported the incident; the incident came to light after passengers complained. The driver is reported to have been suspended from duties. RAIB were not requested to investigate.

Mitcham Junction (London Tramlink) - 29th December 2014 [B-3]

A tram travelling towards Wimbledon, on a segregated section of ballasted track, encountered a facing point Points Position Indicator, displaying a “failed” indication. The driver was instructed to attempt a manual operation of the points. The points were unpowered and in operating the points manually, the points were not properly fitting up and secured, resulting in the tram derailing as it passed over the points. The requirement to correctly move the point manually is described in TOL’s Tram Driver training material and assessment guidelines. However the importance of this requirement in avoiding derailments is not explicitly described to Tram Drivers in their written training material.

The investigation noted that there may be issues related to the points being damaged by trams trailing through the points at excessive speed and recommended that London Trams should consider the current capability or development of TMS to audit average speeds at selected locations on the tramway. The investigation report also noted that TOL should supply LT with copies of its regular speed monitoring reports.

Hong Kong - 17th May 2013 [B-4]

A 761P tram, running between Tin Shui Wai and Yuen Long, derailed as it took a 15 km/h curve at 41 km/h. 77 people were reported to have been injured during the incident. The tram remained upright throughout the incident. The driver was found guilty of committing a negligent act.

New Addington (Croydon Tramlink) - 23rd November 2005 [B-5]

This RAIB investigation considers a collision between two trams on the points leading to a single line section. The following relevant recommendations were made in the RAIB report:

- Tram Operations Ltd should carry out a programme to re-train all their drivers on the necessity to use the hazard brake in an emergency. Training and routine assessments should include understanding and demonstration by the driver in the operation of the hazard brake. The process of 'feathering' to avoid the final jerk should be retained (paragraph 50).
- The Office of Rail Regulation (Her Majesty's Railway Inspectorate) should consider reviewing Railway Safety (Principles and Guidance), Part 2G "Guidance on Tramways" to include the provision of suitable over-run distances, and/or detection and warning systems at the design stage of tramway systems where they are a simple and cost effective means to mitigate against fouling point collisions at the entry to single line sections (paragraph 57).

Norbreck (Blackpool Trams) - 5th August 2009 [B-6]

This RAIB investigation considers a collision with a pedestrian at a tram stop. The following relevant recommendations were made in the RAIB report:

- Blackpool Transport Services (BTS) management should develop and document a company-wide policy for the determination and application of speed limits throughout the network. This should include a maximum speed for non-stopping trams through tram-stops. They should also develop, document, train and brief a speed limit signage policy. The purpose of this recommendation is to introduce a universal speed limit policy, agreed by all parts of BTS and a corresponding speed limit signage policy. These should both be documented. Derivation of any timetables should fully take account of the speed limits applied.
- BTS should develop and document an effective and consistent system to monitor compliance with speed limits among tram drivers, and adjust BTS recruitment, training and compliance procedures as necessary to increase levels of compliance. The purpose of this recommendation is to improve the measurement of levels of non-compliance with speed limits and bring about improved levels.

Phipps Bridge (Croydon Tramlink) - 25th May 2006 [B-7]

This RAIB investigation considers a derailment on facing points. The following relevant recommendations (now more than 10 years old) are made:

- Tram drivers must be trained to be ready to use the emergency brake without hesitation when it is necessary to do so, and this is included in the training given to drivers on the Croydon system.
- A poor relationship exists between TCL and TOL, and this has the potential to affect the safe operation of the tramway.
- Although systems and procedures exist for the co-ordinated management of safety and the exchange of safety related information between the companies, these systems are not being correctly operated. It is important that these problems are addressed before more serious consequences occur. HMRI are aware of these issues and are in discussion with both TCL and TOL, as well as Transport for London, the transport authority from whom TCL hold the concession to operate the system, to develop ways to improve the situation.
- TOL should review its driver training programme, to ensure that the training given to new drivers is keeping risks as low as is reasonably practicable (paragraph 83).

Santiago de Compostela - 24th July 2013 [B-8]

A high speed mainline train, travelling between Madrid and Ferrol, transitioning into ETCS area with an agreed ETCS isolation, derailed as it entered a 80 km/h curve at 190 km/h. The driver is reported to have been using a mobile phone at the time. The incident caused 80 fatalities and 144 injuries. The line has similarities in that there are multiple tunnels with reported difficulties in retaining situational awareness throughout the network but should be noted that this is a high speed system and therefore bound by a different operational concept.

Waterfall, Australia - 31st January 2003 [B-9]

A Tangara (G7) interurban train derailed at speed on a curve near Waterfall, New South Wales, Australia. Seven people were killed, including the driver, after the train driver suffered a heart attack and became incapacitated. The train was travelling at 117km/h (73 mph) on a curve designed for 60km/h (37 mph). The train derailed and overturned, and collided with the cutting sides. Neither the deadman's handle nor the guard had acted to intervene as planned in this scenario.

Philadelphia, 12th May 2015 [B-11]

On May 12, 2015, an Amtrak Northeast Regional train from Washington, D.C. bound for New York City derailed and crashed on the Northeast Corridor in the Port Richmond neighbourhood of Philadelphia, Pennsylvania. Of 238 passengers and 5 crew on board, 8 were killed and over 200 injured, 11 critically. The train was traveling at 102 mph (164 km/h) in a 50 mph (80 km/h) zone of curved tracks when it derailed. Investigation reports cited loss of situational awareness of the train driver after his attention was diverted to an emergency involving another train [B-11][B-12].

References

[B-1] Reports of over speeding from online media: Twitter, Facebook and BBC News:
http://www.bbc.co.uk/news/uk-england-london-37979121
https://twitter.com/bbcbreaking/status/796337315664818178
https://twitter.com/ITS_ESEOSA/status/796499190784421888
https://www.facebook.com/andy.nias/posts/10154172338409075

[B-2] http://www.bbc.co.uk/news/uk-england-manchester-38206072

[B-3] Investigation into Tram derailment near Mitcham Junction, London Tramlink, 29th December 2014 (Report NAL/2392)

[B-4] http://www.scmp.com/news/hong-kong/article/1712320/light-rail-driver-guilty-negligence-over-yuen-long-derailment

[B-5] RAIB Report - New Addington, 23rd November 2005.

[B-6] RAIB Report – Norbreck (Blackpool), 5th August 2009.

[B-7] RAIB Report – Phipps Bridge (Croydon Tramlink), 25th May 2006.

[B-8] http://www.ciras.org.uk/case-studies/case-studies-container/case-study-4-chris-langer-santiago-de-compostela/

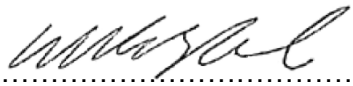
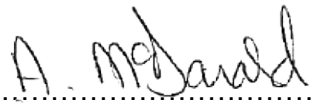
[B-9] Special Commission of Inquiry into the Waterfall Rail Accident, Final Report, Volume 1, January 2005. The Honourable Peter Aloysius McInerney QC.

[B-10] Trams Complaints Summary, 16th October 2016 to 12th November 2016 (Period 8, 2016-2017).

[B-11] https;//www.ntsb. gov/investigations/AccidentReports/Pages/DCA15MR010_Preliminary.aspx

[B-12] https://www.ntsb.gov/news/press-releases/Pages/PR20160517.aspx

For more information please contact:

Originator :	 ..... **Wendy McCristal** **Principal Human Factors Consultant**	**Date:** 10/01/18
Checked By :	 ..... **Phil Cordon** **Team Leader, Risk & Safety**	**Date:** 10/01/18
Approved By :	 ..... **Andy McDonald** **Director, Systems Consulting & Assurance**	**Date:** 10/01/18

Appendix 2

Summary of the Rail Accident Investigation Branch (RAIB) and TfL's independent investigation recommendations and progress against these

1 Background

1.1 The following table presents the RAIB's recommendations and those from our independent investigation into the Tram overturning and derailment at Sandilands junction on 9 November 2016. It summarises our progress to date against the recommendations. (Those recommendations that are greyed out are not directly on us.)

1.2 TfL via London Trams are represented on the UK Trams Sandilands Sub Committee, established to specifically consider RAIB's findings and coordinate a response, and take action, on behalf of the UK Tram Industry. Where we have developed our own solutions to the recommendations we have shared these with the wider industry and will continue to do so. We will also continue to engage with the UK Tram Industry to input to and adopt the outcomes of the wider recommendations/actions.

1.3 Our investigation report is included as Appendix 1 and RAIB's report can be accessed via the link below.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/665906/R182017_171207_Sandilands.pdf

1.4 Future progress updates against these actions will be included in the quarterly Health, Safety Environment performance report to the Safety Sustainability and Human Resources Panel.

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
RAIB recommendation 1	ORR should work with the UK tram industry to develop a new body to enable more effective UK-wide cooperation on matters related to safety, and the development of common standards and good practice guidance. As a minimum, the purpose and aims of this body should be to: i. provide a forum for the discussion of common safety issues and the exchange of experience; ii. the provision of authoritative and impartial advice and guidance on matters related to safety; iii. managing the development of safety related design and operational standards, and their subsequent maintenance; iv. participation in the development of industry standards and guidance by international bodies; v. sponsoring and project management of the research and development needed to inform the above; vi. gathering data, monitoring and reporting on the industry's safety performance (including comparisons of safety performance on different tramways); vii. providing suitable guidance on effective safety management, including guidance applicable to public highways; viii. working with tramways to help the plans for industry safety improvement; and ix. disseminating good practice from both the UK and overseas industries. The body should be suitably constituted and funded to enable the effective delivery of the above functions. It should be structured so that the ORR promotes, encourages and supports its operation.	ORR			ORR has invited TfL to an UK tram industry wide forum on 22 January to discuss approaches to meet the intent of this recommendation.

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
RAIB Recommendation 2 links with RAIB Recommendation 1 RAIB Recommendation 10 TFL Recommendation 5	UK tram operators, owners and infrastructure managers should jointly conduct a systematic review of operational risks and control measures associated with the design, maintenance and operation of tramways. The review should include: i. examination of the differing risk profiles of on-street, segregated and off-street running; ii. safety issues associated with driving at relatively high speeds in accordance with the line of sight principle in segregated and off-street areas, particularly during darkness and when visibility is poor; iii. current practice world-wide and the potential of recent technological advances to help manage residual risk; iv. safety learning from bus and train sectors that may be applicable to the design and operation of tramways; v. consideration of the factors that affect driver attention and alertness across all tram driving scenarios in comparison to driving buses and trains; and vi. guidance on timescales for implementing new control measures (e.g. whether retrospective or only for new equipment). Using the output of this review UK tram operators, owners and infrastructure managers should then, in consultation with ORR, publish updated guidance on ways of mitigating the risk associated with design, maintenance and operation of UK tramways.	UK Tram Operators, Owners & Infrastructure Managers (ORR)	- Partially dependent on the output of the review of risk assessments / network risk profile (RAIB Recommendation 10) - Partially dependent upon the establishment of the industry body referred to in RAIB Recommendation 1 - Output from this will also directly meet the intent of SNCL Recommendation 5	Director of London Trams (LT)	TfL/LT are represented on the industry's UK Trams Sandilands Sub Committee, established to consider RAIB's findings and coordinate a response, and take action, on behalf of the UK Tram Industry. Work underway to review and improve route risk assessments / network risk model by LT/TOL has already commenced and will be shared with the wider industry (RAIB Recommendation 10 & SNCL recommendation 5). TfL hosting a UK Rail industry safety summit on 1st February 2018, where the industry wide element of this recommendation will be discussed further.
RAIB recommendation 3 links with TfL Recommendation 2	UK tram operators, owners and infrastructure managers should work together to review, develop, and install suitable measures to automatically reduce tram speeds if they approach higher risk locations at speeds which could result in derailment or overturning.	UK Tram Operators, Owners and Infrastructure Managers	- the TfL/LT work stream looking at physical prevention of over speeding directly meets intent of this recommendation	Director of London Trams	Via a global search, LT has investigated potential automatic speed reduction solutions that meet the intent of the RAIB recommendation. LT has developed a high level system architecture for a potential over speed control solution appropriate to its vehicles, and is in the process of assessing the impact and technical requirements of such a system before entering the procurement market. LT has shared its work to date with UK Trams and will continue to do so.

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
RAIB recommendation 4	UK tram operators, owners and infrastructure managers should work together to research and evaluate systems capable of reliably detecting driver attention state and initiating appropriate automatic responses if a low level of alertness is identified. Such responses might include an alarm to alert the tram driver and/or the application of the tram brakes. The research and evaluation should include considering use of in-cab CCTV to facilitate the investigation of incidents. If found to be effective, a time-bound plan should be developed for such devices to be introduced onto UK tramways	UK Tram Operators, Owners & Infrastructure Managers	- TfL/LT's In-cab vigilance device directly meets the intent of this recommendation	Director of London Trams	Complete for TfL/LT.After a market search for suitable technologies LT has procured and commissioned the Seeing Machine Guardian driver protection system fleet wide. This system provides proven driver fatigue and distraction management via facial recognition technology. Driver protection system installed and operational across LT fleet.TfL/LT are represented on the industry's UK Trams Sandilands Sub Committee, established to consider RAIB's findings and coordinate a response, and take action, on behalf of the UK Tram Industry, our action will be discussed there and considered at the Trams Summit.
RAIB recommendation 5 links with TfL Recommendation 1	UK tram operators, owners and infrastructure managers, in consultation with the DfT, should work together to review signage, lighting and other visual information cues available on segregated and off-track areas based on an understanding of the information required by drivers on the approach to high risk locations such as tight curves. Comparison should be made with the cues provided to road vehicle drivers on highways that are designed in accordance with current UK highway standards. Prior to the installation of an automatic protection system to apply the brakes (RAIB Recommendation 3) consideration should also be given to providing in cab warnings to tram drivers on the approach to high risk locations. The findings of this review should then be used by UK tram operators and tramway owners to improve the information and/or warnings provided to drivers at high risk locations in segregated and off-track areas.	UK Tram Operators, Owners & Infrastructure Managers in consultation with the DfT	- Work has commenced on establishing activity required to meet the intent of this recommendation	Director of London Trams	A TfL/LT review is underway and has to date resulted in the following changes: 1) Reduction in maximum network speed from 80kph to 70 kph/ 2) Introduction of step down speeds and associated signage on approach to high risk locations/ and 3) Provision of additional high visibility outlines to relevant speed signage. TfL/LT are represented on the industry's UK Trams Sandilands Sub Committee, established to consider RAIB's findings and coordinate a response, and take action, on behalf of the UK Tram Industry, our solution will be shared there and at the Trams Summit.

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
RAIB recommendation 6 links with TfL recommendation 8	UK tram operators and owners should, in consultation with appropriate tram manufacturers and other European tramways, review existing research and, if necessary, undertake further research to identify means of improving the passenger containment provided by tram windows and doors. The findings should then be used to: i. provide a time-bound plan to modify doors and windows on existing trams when practical to do so (eg during planned refurbishment); ii. promote changes to the specifications and standards governing the doors and windows of new trams; and iii. inform the Department for Transport of the findings to allow implementation of the safety advice at paragraph 492.	UK Tram Operators & Owners	- TfL/LT's work stream to review glazing specification partially meets intent of this recommendation- Output from this will also directly meet the intent of SNCL Recommendation 8	Director of London Trams	TfL/LT has separated its response to this recommendation into two parts: 1. Glazing. LT has commissioned the manufacture and testing of several prototypes that may provide an appropriate level of additional containment. These prototypes have been assessed against the conditions likely to have been encountered during the Sandilands incident, and will take into account any affect they may have on ease of access for the emergency services. 2. Doors. LT is investigating the practicalities of modifying tram doors and we will consider the recommendations made by the RAIB when designing new vehicles in the future. .As TfL/LT are represented on the industry's UK Trams Sandilands Sub Committee, established to consider RAIB's findings and coordinate a response, and take action, on behalf of the UK Tram Industry, our proposals will be shared there and at the Trams Summit.
RAIB recommendation 7	UK tram operators and owners should install (or modify existing) emergency lighting so that the lighting cannot be unintentionally switched off or disconnected during an emergency.	UK Tram Operators & Owners	- TfL/LT's work stream to review emergency lighting meets intent of this recommendation	Director of London Trams	LT has commissioned a study into possible options relating to emergency lighting on its trams, and is preparing to enter into industry procurement of an appropriate solution.
RAIB recommendation 8	UK tram operators and owners should review options for enabling the rapid evacuation of a tram which is lying on its side after an accident. If the review identifies practical measures which would provide significant benefit to trapped passengers, UK tram operators and owners should: i. implement these measures on existing trams if practical to do so in the short term; or ii. provide a time-bound plan to implement these measures on existing trams when practical to do so (eg during planned refurbishment). Such measures should then be promoted for inclusion in the specifications and standards governing the new builds of trams.	UK Tram Operators & Owners		Head of Engineering London Rail (which covers London Trams)	We will work with UK Trams, other tram operators and tram manufacturers to identify and evaluate options to achieve this objective.

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
RAIB recommendation 9	The Office of Rail and Road should carry out a review of the regulatory framework for tramways and its long-term strategy for supervision of the sector. This should be informed by a new assessment of the risk associated with tramway operations (allowing for low frequency/high consequence events of the type witnessed at Sandilands junction) and consideration of the most effective means by which supervision can contribute to continuous improvement in passenger safety.	ORR			
RAIB recommendation 10 links with RAIB Recommendation 2	Tram Operations Limited and London Trams should commission an independent review of its process for assessing risk associated with the operation of trams (e.g. collision, derailment and overturning of trams). This review shall consider: i. the extent to which the process for risk assessments is capable of identifying and correctly assessing all significant risks, particularly those related to low frequency/high consequence events; and ii. the means by which potential mitigations are identified and evaluated.The finding of the review shall be incorporated into a documented process for the assessment of operational risk. This should also be shared with other tramways. Note: The requirement for an independent review does not prevent it from being carried out by others parts of TfL or First Group provided the requisite expertise is available	Tram Operations Limited & London Trams	- Programme of work agreed with Tram Operations Limited to review and make improvements to route risk assessments and network risk model.	London Trams - Senior HSE Manager	Programme agreed, resources allocated and activities underway. Project execution plans shared with the ORR. Route risk assessments and risk model have been reviewed and updated.
RAIB recommendation 11	Tram Operations Limited, drawing on expertise from elsewhere in the FirstGroup organisation, should review and, where necessary, improve the management of fatigue risk affecting its tram drivers with reference to the ORR's good practice guidance. As a minimum this should include a review of: - the base roster with particular reference to whether it is appropriate to use a shift rotation pattern of about a week; - the management of rest day working and working time exceedances; - training, briefings and support for tram drivers regarding lifestyle, sleep hygiene and their individual responsibilities regarding fatigue and fitness for duty (including reporting when they feel that fatigue may affect their driving performance).	Tram Operations Limited			

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
RAIB recommendation 12	Tram Operations Limited should commission an external expert or organisation to review, the way that it learns from operational experience. The areas the review should address are: - fostering the creation of a 'just culture' in which staff are more likely to report incidents and safety-related concerns; - establishing a common understanding of what constitutes a safety incident when reported by the public, or that should be reported by staff; - improving management systems to ensure that safety issues are properly identified from any reports, whether from staff or members of the public, and that appropriate and timely actions are taken in response; and - developing improved processes to ensure that suitable lessons are learned by TOL from such reports and that outcomes are fed back to the reporter.	Tram Operations Limited			
RAIB recommendation 13	Tram Operations Limited and London Trams should, in conjunction with TfL, improve processes, and where necessary, equipment used for following up both public and employee comments which indicate a possible safety risk. The improved process should ensure complaints are dealt with promptly and within time periods which: i. improve the effectiveness of identifying complaints that are safety related (eg time, date, location, safety or customer care event etc.); ii. avoid the loss of technical evidence (eg CCTV recordings); iii. minimise the time before witness information is sought; and iv. ensure that appropriate action is taken without undue delay.	Tram Operations Limited & London Trams	- A review of TfL/LT's complaints process is complete, with a revised process implemented. - Internal audit currently ongoing to identify any gaps in new process.	Director London Trams/General Counsel	Complete. Substantial improvements have been implemented in this area following Sandilands, with a pan-TfL procedure PR0725 'Managing Safety & Security Complaints' developed and implemented via the TfL Management System. There is an Internal Audit underway to assure the extent to which this revised procedure has been effectively implemented, of which London Trams is in scope.
RAIB recommendation 14	Tram Operations Limited and London Trams should review, and where necessary, improve their processes for inspection and maintaining on-tram CCTV equipment to greatly reduce the likelihood of recorded images being unavailable for accident and incident investigation. This recommendation may apply to other UK tram operators.	Tram Operations Limited & London Trams	- No gaps identified	Director of London Trams	Complete. All LT fleet has been fitted with new CCTV image recorders. CR4000 has CCTV health checkers which actively monitor the status of recording units and identify faults in real time. Work underway to establish route to market for the fitment of similar monitoring technology for Stadler units.

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
RAIB recommendation 15	London Trams and Tram Operations Limited should:- review and, where necessary, revise existing tram maintenance and testing documentation to take account of experienced gained, and modifications made, since the trams were brought into service; and- review and, where necessary, revise the processes for ensuring that these documents are kept up-to-date in future.	London Tram/Tram Operations Limited	- TfL/LT's work stream to review Engineering/Maintenance Standards is looking at Maintenance Task Instructions and the review of the Fleet Vehicle Maintenance Instructions	Head of Engineering London Rail (which covers London Trams)	LT has undertaken a comprehensive review of its written standards, maintenance processes and forms and identified quality gaps.LT will shortly appoint an independent entity who will author new written standards, maintenance processes and forms addressing all quality gaps. This process will be in two phases, with sixteen critically prioritised standards and associated documents being delivered in the first phase.
TfL recommendation 1 links with RAIB Recommendation 5	Review available cues to the driver of the braking points and the approaching curve	London Trams	- TfL/LT work stream to introduce Step down speeds, reduce maximum speed from 80kph to 70 kph and to increase size of signs/visibility directly meets the intent of this recommendation	Director of London Trams	Complete. Overall network top speed has been reduced from 80kph to 70kph. Additional 70kph signs have been provided to aid driver awareness of the permitted maximum speed. A design and signal sighting exercise has been concluded and the provision of additional step down speed signage to aid driver speed awareness and visual cuing is complete. A design and signal sighting exercise has been concluded and enhanced visibility signs provided, which will heighten driver speed awareness in high risk areas.
TfL recommendation 2 links with RAIB Recommendation 3	Review of arrangements for the monitoring and management of speeding	London Trams	- TfL/LT work stream to consider implementation of the ibus system onto Trams (iTram system) and the work stream to consider physical prevention of over-speeding directly meets the intent of this recommendation	Director of London Trams	LT has commissioned the installation and commissioning of the iTram system, which will via GPS technology provide driver over-speed alerts network wide. iTram will also provide oncoming hazard awareness to drivers of high risk areas.

Source	Recommendation	Aimed at	TfL/LT Management Action	Owner for TfL	Progress to Date
TfL recommendation 3	Review of traction brake controller (TBC) driver's safety device (DSD) design	London Trams	- Intent of this recommendation being met by the introduction of Driver Protection Device (RAIB Recommendation 4)	Head of Engineering London Rail (which covers London Trams)	Complete. After a market search for suitable technologies LT has procured and commissioned the Seeing Machine Guardian driver protection system fleet wide. This system provides proven driver fatigue and distraction management via facial recognition technology.
TfL recommendation 4 - Same as RAIB recommendation 11	Review the arrangements for the monitoring and management of fatigue and fitness to work			Director of London Trams	Closed as duplicated by RAIB Recommendation 11.
TfL recommendation 5 - Same as RAIB Recommendation 10	Review route risk assessments network risk model to reflect new understanding of risk arising from the Sandilands investigation			London Trams - Senior HSE Manager	Closed as duplicated by RAIB Recommendations 10.
TfL recommendation 6 - same as RAIB Recommendation 12	Review mechanisms used to promote Organisation Learning			Director of London Trams	Closed as duplicated by RAIB Recommendation 12.
TfL recommendation 7 - same as RAIB Recommendation 12	Review near miss reporting mechanisms			Director of London Trams	Closed as duplicated by RAIB Recommendation 12.
TfL recommendation 8 - Same as RAIB Recommendation 6	Consider feasibility of increasing containment of tram vehicles			Director of London Trams	Closed as duplicated by RAIB Recommendation 6.